KESETIMBANGAN MASSA

Q&A

Soal 1

a. Dalam sebuah pemanas (*furnace*), 95% karbon diubah menjadi CO_2 & sisanya menjadi CO. Hitung jumlah gas-gas yang keluar dari cerobong
b. 20 kg garam ditambahkan ke dalam 100 kg air menghasilkan larutan dengan densitas 1323 kg m^{-3}. Tentukan konsentrasi garam dalam %b/b dan %b/v.
c. Dalam proses karbonasi minuman ringan, diperlukan 3 volume gas CO_2 tiap 1 volume air pada 0^oC, tekanan atmosfer. Tentukan fraksi massa (% b/b) dan fraksi mol CO_2 dengan mengabaikan komponen selain CO_2 dan air.

1a

1. *Basis is 1 kg of carbon*
2. *The combustion equations are*

$$C + O_2 = CO_2$$

$$C + \tfrac{1}{2}O_2 = CO$$

3. *From these equations, 44 kg carbon dioxide is formed by combustion of 12 kg carbon, and 28 kg carbon monoxide is formed by combustion of 12 kg carbon.*
4. *Then, the amount of CO_2 produced,*

$$\frac{(44\ kg\ CO_2)(0.95\ kg\ C\ burned)}{12\ kg\ C\ burned} = 3.48\ kg\ CO_2$$

5. *Similarly, the amount of CO produced,*

$$\frac{(28\ kg\ CO)(0.05\ kg\ C\ burned)}{12\ kg\ C\ burned} = 0.12\ kg\ CO$$

6. *Thus, the flue gases contain 3.48 kg CO_2 and 0.12 kg CO for every kilogram of carbon burned.*

1b:

% b/b = (20 / (100 + 20)) * 100% = 16,67%

1 m^3 larutan → 1323 kg larutan

mengandung (16,67% * 1323 kg)

= 220,5 kg garam dalam 1 m^3 larutan (dalam 1 L?)

% b/v = (220,5 / 1000) * 100% = 22,05%

1c.

Basis 1 liter air = 1000 g

Volume gas CO_2 = 3 liter

$$p\,V = n\,R\,T$$

$1 * 3 = n * 0{,}08206 * 273$

n = 0,134 mol

n = berat / BM → 0,134 = berat / 44

Berat CO_2 = 5,9 g

% b/b = (5,9 / (1000+5,9)) * 100%

Fraksi mol = 0,134 / ((1000/18) + 0,134)

Soal 2

- Suatu makanan (basah) mengandung 70% air. Setelah pengeringan 80% dari air mula-mula akan diuapkan.

  (a) massa air hilang per kg makanan (basah)?

  (b) komposisi makanan kering?

1. *Select basis = 1 kg wet food product*
2. *Mass of water in inlet stream = 0.7 kg*
3. *Water removed in drying = 0.8(0.7) = 0.56 kg/kg of wet food material*
4. *Write material balance on water,*

$$\text{Water in dried food} = 0.7(1) - 0.56 = 0.14\ \text{kg}$$

5. *Write balance on solids,*

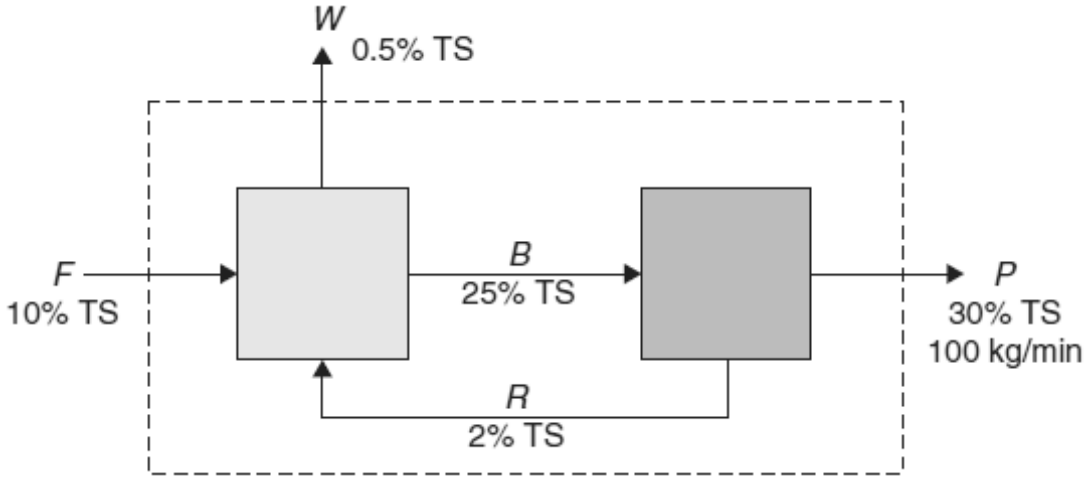
$$0.3(1) = \text{solids in exit stream}$$

$$\text{Solids} = 0.3\ \text{kg}$$

6. *Thus, the dried food contains 0.14 kg water and 0.3 kg solids.*

Soal 3

- Pengentalan “padatan total (TS)” suatu makanan cair dari 10% menjadi 30% dalam 2 tahap
- Th 1. keluarnya cairan TS konsentrasi rendah
- Th 2. pemisahan produk cairan TS konsentrasi rendah yang kembali ke Th 1 (*Recycle*).
- Hitung besarnya laju *recycle* ketika *recycle* mengandung 2% TS, limbah Th 1 mengandung 0.5% TS, & hasil antara Th 1 & 2 mengandung 25% TS. Proses menghasilkan 100 kg/min dengan 30% TS.



1. *Select 1 min as a basis.*
2. *For the total system*

$$F = P + W$$

$$Fx_F = Px_p + Wx_w$$

$$F = 100 + W$$

$$F(0.1) = 100(0.3) + W(0.005)$$

where x is the solids fraction.

3. *For the first stage*

$$F + R = W + B$$

$$Fx_F + Rx_R = Wx_W + Bx_B$$

$$F(0.1) + R(0.02) = W(0.005) + B(0.25)$$

4. *From step (2)*

$$(100 + W)(0.1) = 30 + 0.005W$$

$$0.1W - 0.005W = 30 - 10$$

$$0.095W = 20$$

$$W = 210.5 \text{ kg/min}$$

$$F = 310.5 \text{ kg/min}$$

5. *From step (3)*

$$310.5 + R = 210.5 + B$$

$$B = 100 + R$$

$$310.5(0.1) + 0.02R = 210.5(0.005) + 0.25B$$

$$31.05 + 0.02R = 1.0525 + 25 + 0.25R$$

$$4.9975 = 0.23R$$

$$R = 21.73 \text{ kg/min}$$

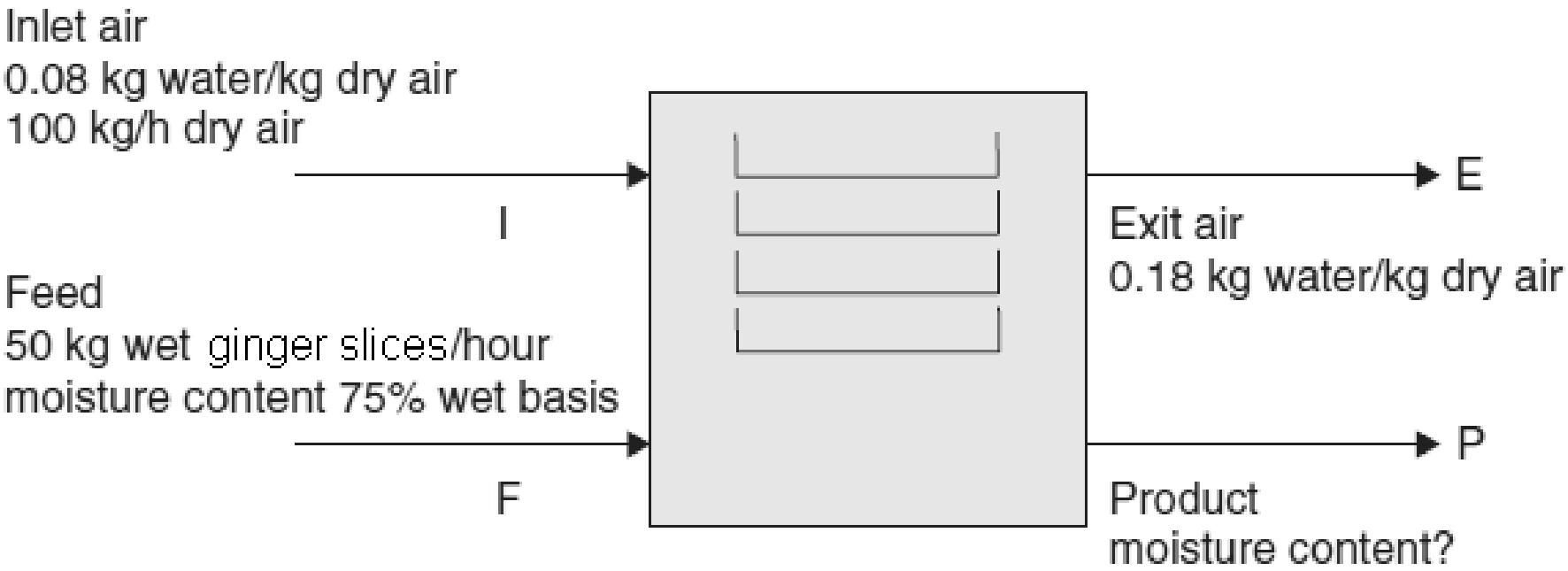
6. *The results indicate that the recycle stream will be flowing at a rate of 21.73 kg/min.*

Soal 4

- Jahe iris dengan k.a. 75% wb dikeringkan dalam sebuah pengering. Kandungan air di udara yang masuk ke pengering 0,08 kg air per 1 kg udara kering. Kandungan air dari udara yang keluar dari pengering 0,18 kg air per 1 kg udara kering. Laju aliran udara ke dalam pengering 100 kg udara kering per jam. Sebanyak 50 kg jahe iris masuk pengering per jam. Pada *steady state*, hitung:

a. Laju aliran massa jahe kering

b. Kadar air (db) jahe kering


Inlet air
0.08 kg water/kg dry air
100 kg/h dry air
I
Feed
50 kg wet ginger slices/hour
moisture content 75% wet basis
F
E
Exit air
0.18 kg water/kg dry air
P
Product
moisture content?

1. *Basis* $= 1\,h$
2. *Mass of air entering the drier* $=$ *mass of dry air* $+$ *mass of water*

$$I = 100 + 100 \times 0.08$$

$$I = 108\,kg$$

3. *Mass of air leaving the drier* $=$ *mass of dry air* $+$ *mass of water*

$$E = 100 + 100 \times 0.18$$

$$E = 118\,kg$$

4. *Total balance on the drier*

$$I + F = E + P$$

$$108 + 50 = 118 + P$$

$$P = 40\,kg$$

5. *Solid balance on the drier*

$$1 - MC_{wb} = 1 - \frac{mass\ of\ water}{mass\ of\ moist\ sample}$$

or

$$1 - MC_{wb} = \frac{mass\ of\ dry\ solids}{mass\ of\ moist\ sample}$$

or

$$Mass\ of\ dry\ solids = Mass\ of\ moist\ sample\ (1 - MC_{wb})$$

Therefore,

$$Mass\ of\ solid\ content\ in\ feed = F(1 - 0.75)$$

If y is the solid fraction in the product stream P, then solid balance on the drier gives

$$0.25\ F = y \times P$$

$$y = \frac{0.25 \times 50}{40}$$

$$= 0.3125$$

Thus,

$$\frac{\text{mass of dry solids}}{\text{mass of moist sample}} = 0.3125$$

or

$$1 - \frac{\text{mass of dry solids}}{\text{mass of moist sample}} = 1 - 0.3125$$

Therefore, moisture content (wet basis) in the exit ginger stream is

$$1 - 0.3125 = 0.6875$$

6. *The wet basis moisture content is converted to dry basis moisture content*

$$MC_{db} = \frac{0.6875}{1 - 0.6875}$$

$$MC_{db} = 2.2\,kg\ water\ per\ 1\,kg\ dry\ solids$$

7. *The mass flow rate of ginger exiting the drier is 40 kg at a moisture content of 2.2 kg per 1 kg dry solids.*

Soal 5

- Susu skim dihasilkan dari pemisahan sebagian lemak dari susu. Susu skim mengandung 90,5% air, 3,5% protein, 5,1% karbohidrat, 0,1% lemak & 0,8% abu. Jika sebelumnya susu mengandung 4,5% lemak, hitung komposisi susu awal, dengan asumsi hanya lemak yang terpisahkan dan tidak ada massa yang hilang selama pembuatan susu skim

Basis perhitungan : misalkan 100 kg susu skim

Lemak susu skim = 0,1 kg

Lemak susu murni = (x + 0,1) kg

Total massa susu murni = (100 + x) kg

Lemak susu murni = (x+0,1)/(100+x) * 100% = 4,5%

x = 4,6 kg

Total massa susu murni = 100 + 4,6 = 104,6 kg

Komposisi susu murni :

- Lemak = 4,5%
- Air = (90,5/104,6) * 100% = 86,52%
- Dengan cara yang sama, Protein = 3, 35 %; karbohidrat = 4,88%;

  abu = 0,76%

Soal 6

- Sebanyak 35.000 kg susu (4% lemak) dipisahkan dengan cara sentrifugasi selama 6 jam menjadi susu skim (0,45% lemak) dan krim (45% lemak)
- Berapa laju alir kedua output?
- Basis : 1 jam aliran bahan masuk

- **Bahan masuk**
- (35.000 / 6) = 5833 kg per jam
- Lemak = 4% * 5833 kg = 233 kg
- Non lemak = 5833 – 233 = 5600 kg

- **Produk keluar**
- Krim = x → Lemak = 0,45 * x
- Skim = 5833 – x → Lemak = 0,0045 * (5833 – x)

- **Kesetimbangan massa untuk lemak**
- Lemak masuk = lemak keluar
- 233 = 0,45 x + 0,0045 * (5833 – x)
- x = 465
- Laju alir krim = 465 kg / jam
- Laju alir susu skim = (5833 – 465) kg / jam

Soal 7

- Suatu unit pengolahan daging akan mencampur daging sapi A (23% lemak) dengan daging sapi B (5% lemak) untuk mendapatkan daging campuran dengan lemak 15%.
- Tentukan proporsi pencampurannya; dan tentukan berapa jumlah daging A dan B untuk memperoleh 200 kg daging campuran.

- Lemak masuk = lemak keluar
- 0,23 A + 0,05 B = 0,15 (A+B)
- 0,08 A = 0,1 B
- A / B = 5 / 4

- Untuk 200 kg daging
- A = (5/9). 200 kg
- B = (4/9). 200 kg

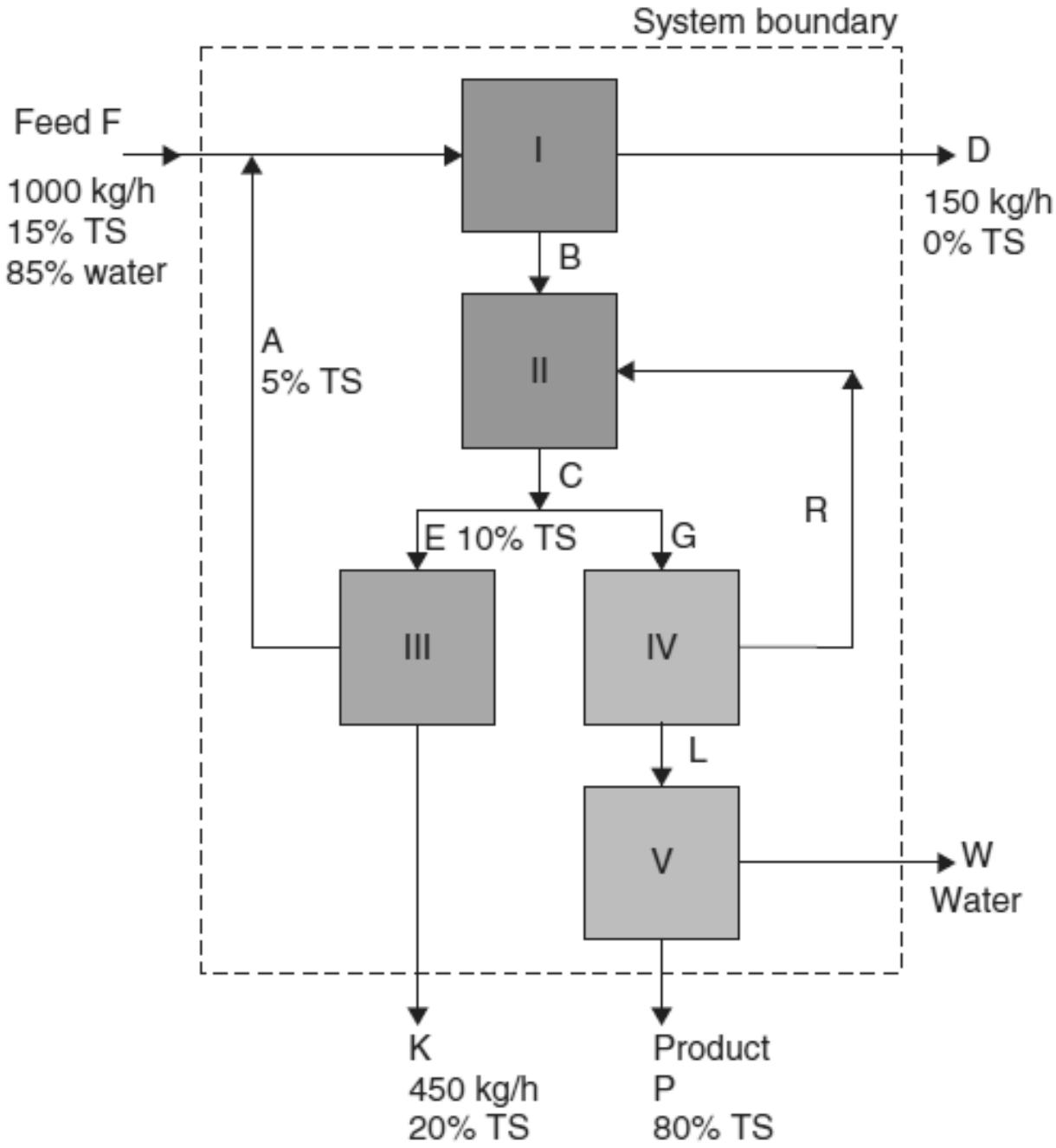
Soal 8

- Suatu makanan akan diolah dalam 5 tahap. Bahan masuk 1000 kg/jam dengan data-data seperti pada gambar (komposisi masing-masing aliran dinyatakan dalam padatan dan air). Hasil *C* terbagi rata menjadi *E & G* . Produk *P* diinginkan mengandung 80% padatan. *K* menghasilkan by-product pada laju 450 kg/jam dengan kandungan 20% padatan. Hitung:

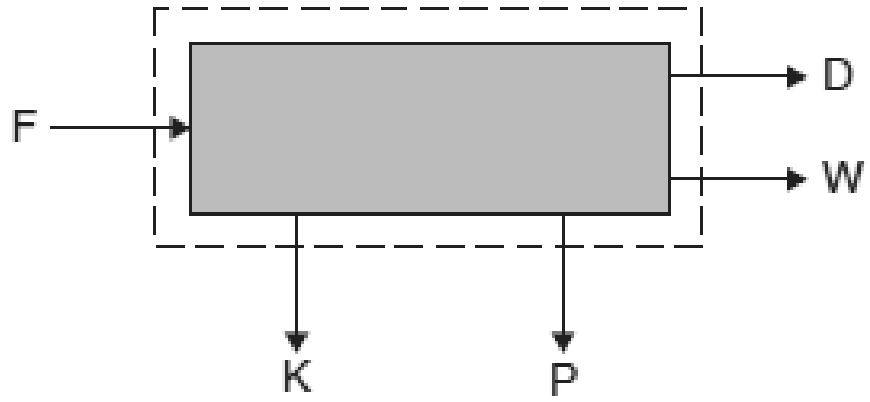
a. Laju massa produk *P* .

b. Laju massa dari *recycle A* .

c. Laju massa dari *recycle R* .



■ A flow sheet of an experimental food manufacturing system.



Total system

1. *Basis = 1 h*
2. *Consider total system, solid balance (Fig. E1.9).*

$$0.15 \times F = 0.2 \times K + 0.8 \times P$$

$$0.15 \times 1000 = 0.2 \times 450 + 0.8 \times P$$

$$150 = 90 + 0.8 \times P$$

$$P = \frac{60}{0.8} = 75\ kg$$

$$P = 75\ kg$$

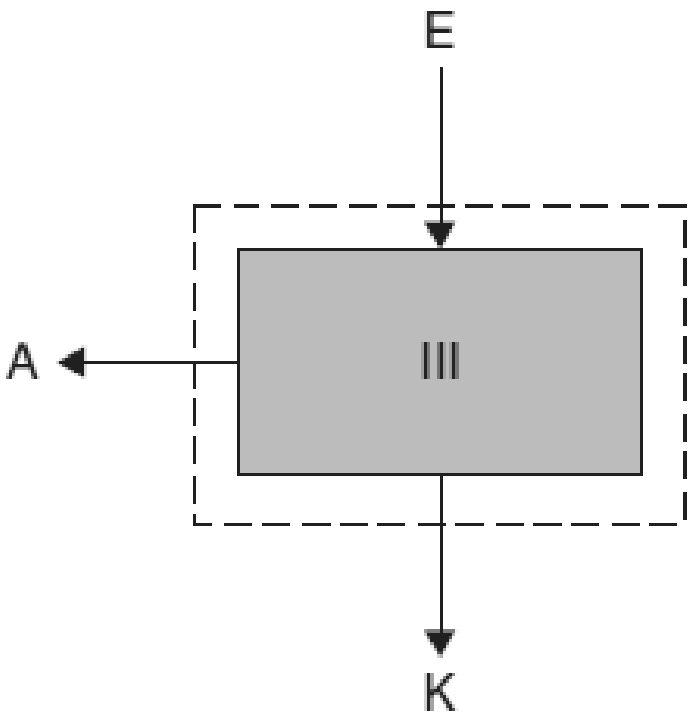


Illustration of stage III

3. *Consider stage III*

Total balance

$$E = A + K; \quad E = A + 450$$

Solid balance

$$0.1E = 0.05A + 0.2K$$

$$0.1E = 0.05A + 0.2 \times 450$$

$$0.1E = 0.05A + 90$$

Solve preceding Equations (1) and (2) simultaneously.

$$E = 1350\ kg$$

$$A = 900\ kg$$

4. *Since C is divided equally into E and G,*

$$G = 1350\ kg \text{ with } 10\% \text{ solid}$$

5. *For total system, conduct total balance to find W.*

$$F = K + P + D + W$$

$$1000 = 450 + 75 + 150 + W$$

$$W = 325\ kg$$

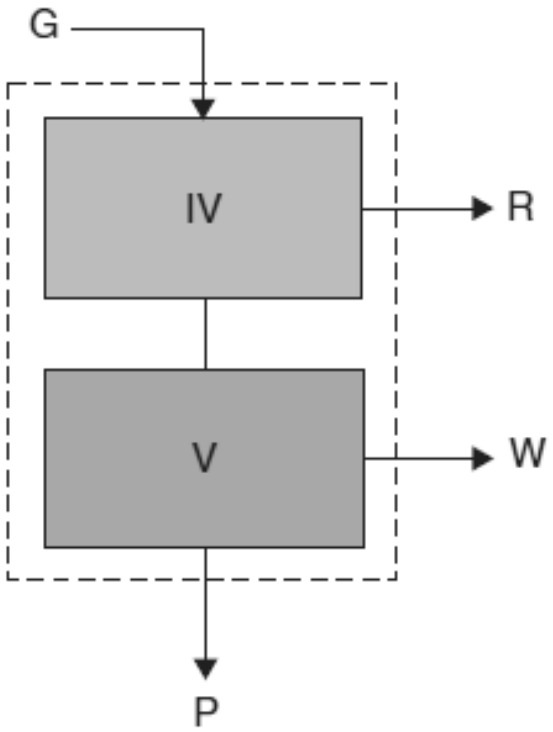


Illustration of stages IV and V

6. *Consider stages IV and V together*

$$G = R + W + P$$

$$1350 = R + 325 + 75$$

$$R = 950\,kg$$

7. *The mass flow rates of stream P, A, and R are 75 kg, 900 kg, and 950 kg, respectively.*

Soal 9

- 1 ton kedelai (18% minyak, 35% protein, 27,1% karbohidrat, 9,4% serat+abu, 10,5% air) diolah sebagai berikut :
- Pengepresan → kadar minyak berkurang menjadi 6%
- Ekstraksi hexane → menghasilkan *meal* kadar minyak 0,5%
- Pengeringan → kadar air 8%
- Susun kesetimbangan massa penyusun kedelai
- Basis : 1000 kg
- Mass in = mass out

- Bahan masuk = 180 kg minyak + 820 kg bahan lain
- Hasil tahap 1 = 6% minyak + 94% bahan lain
- Minyak dalam hasil tahap 1 = (6/94) * 820 = 52,3 kg
- Minyak dikeluarkan = 180 – 52,3 = 127,7 kg

- Hasil tahap 2 = 0,5% minyak + 99,5% bahan lain
- Minyak dlm hasil tahap 2 = (0,5/99,5) * 820 = 4,1 kg
- Minyak dlm hexane = 52,3 – 4,1 = 48,2 kg

- Hasil tahap 3 = 8% air + 92% bahan lain
- Air dlm hasil tahap 3 = (8/92) * 719,1 = 62,5 kg
- Air yang menguap = 105 – 62,5 = 42,5 kg

Mass balance, basis 1000kg soybean entering

Mass in (kg)		Mass out (kg)		
Minyak	180	Minyak terpres		127,7
Protein	350	Minyak dalam hexane		48,2
Karbohidrat	271	Total produk		781,6
Abu & serat	94	terdiri dari		
Air	105	Protein	350	
		Karbohidrat	271	
		Abu & serat	94	
		Air	62,5	
		Minyak	4,1	
		Air teruapkan		42,5
Total	1000	Total		1000

Soal 10

- Baker’s yeast is to be grown in a continuous fermentation system using a fermenter volume of 20m^3 in which the flow residence time is 16h. A 2% inoculum containing 1.2% of yeast cells is induced in the growth medium. This is then passed to the fermenter, in which the yeast grows with a steady doubling time of 2.9h. The broth leaving the fermenter then passes to a continuous centrifuge which produces a yeast cream containing 7% of yeast which is 97% of the total yeast in the broth. Calculate the rate of flow of the yeast cream and of the residual broth from the centrifuge. (Assuming the broth to have a density substantially equal to that of water)

- Fermenter volume = 20 m^3, the residence time 16h,
- flow rate through fermenter = 20/16 = 1.250 m^3 h^{-1}
- Assume density of broth = water, mass flow rate = 1250 kg h^{-1}
- Yeast concentration in the liquid flowing to the fermenter = (concentration in inoculum) / dilution of inoculum
  = (1.2/100) / (100/2) = 2.4 x 10^{-4} kg kg^{-1}
- The yeast mass doubles every 2.9h.
- In 2.9h, 1 kg → 1 x 2^1 = 2 kg
- In 16h → 16/2.9 = 5.6 doubling times
- 1 kg yeast grows to 1 x $2^{5.6}$ kg = 48.5 kg
- Yeast leaving fermenter = initial concentration * growth * flow rate
  = 2.4 x 10^{-4} x 48.5 x 1250 = 15 kg h^{-1}
- Yeast-free broth flow = (1250 – 15) = 1235 kg h^{-1}
- From the centrifuge flows a (yeast rich) stream with 7% yeast = 97% of the total yeast:
- Stream = (15 x 0.97) x 100 / 7 = 208 kg h^{-1}
- The broth (yeast lean) stream = (1250 – 208) = 1042 kg h^{-1}
- contains (15 x 3/100) = 0.45 kg h^{-1} yeast
- Yeast concentration in the residual broth = 0.45 / 1042 = 0.043%

SOAL 11

- A pilot plant model of a falling film evaporator has an evaporation capacity of 10 kg/h of water. The system consists of a heater through which the fluid flows down in a thin film, and the heated fluid discharges into a collecting vessel maintained under a vacuum in which flash evaporation reduces the temperature of the heated fluid to the boiling point. In a continuous operation, a recirculating pump draws part of the concentrate from the reservoir, mixes this concentrate with feed, and pumps the mixture through the heater. The recirculating pump moves 20 kg/h of fluid. The fluid in the collecting vessel should be at the desired concentration for withdrawal from the evaporator at any time. If feed enters at 5.5% solids and a 25% concentrate is desired, calculate (a) the feed rate and concentrate production rate, (b) the amount of concentrate recycled, and (c) the concentration of the mixture of feed and recycled concentrate