TEMA 5. AUTOEVALUACIÓN

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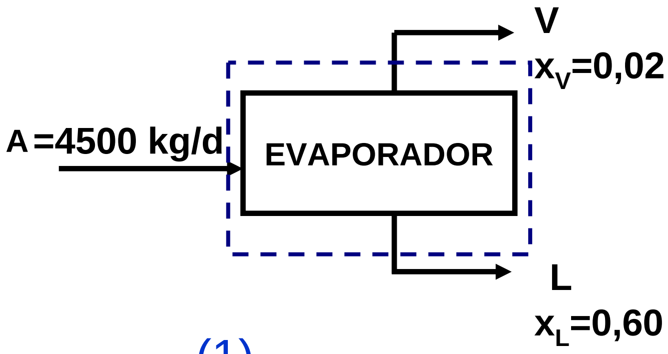
Problema 2: solución

F_A= 4500 kg/d
x_A=0,21

a) V, L



EVAPORADOR

M.B. Total $$A - V - L = 0 \quad \left[\frac{kg}{día}\right] \qquad (1)$$

M.B. Parcial (sólidos) $$A\left[\frac{kg}{dia}\right]\cdot X_A\left[\frac{kg_{Solid}}{kg}\right] - V\left[\frac{kg}{dia}\right]\cdot X_V\left[\frac{kg_{Solid}}{kg}\right] - L\left[\frac{kg}{dia}\right]\cdot X_L\left[\frac{kg_{Solid}}{kg}\right] = 0 \quad \left[\frac{kg_{solid}}{día}\right] \qquad (2)$$

Solución:

Ec. (1): $$4500 - V - L = 0 \quad \left[\frac{kg}{día}\right]$$

Ec. (2): $$4500\left[\frac{kg}{dia}\right]\cdot 0,21\left[\frac{kg_{Solid}}{kg}\right] - V\left[\frac{kg}{dia}\right]\cdot 0,02\left[\frac{kg_{Solid}}{kg}\right] - L\left[\frac{kg}{dia}\right]\cdot 0,60\left[\frac{kg_{Solid}}{kg}\right] = 0 \quad \left[\frac{kg_{solid}}{día}\right]$$

Ec. (1) y (2):

$$945 - V\cdot 0,02 - \left(4500 - V\right)\cdot 0,60 = 0$$

$$945 - V\cdot 0,02 - 2700 + V\cdot 0,60 = 0$$

$$V = 3026 \left[\frac{kg}{día}\right]$$

Ec. (1): $$4500 - 3026 - L = 0$$

$$L = 1474 \left[\frac{kg}{día}\right]$$

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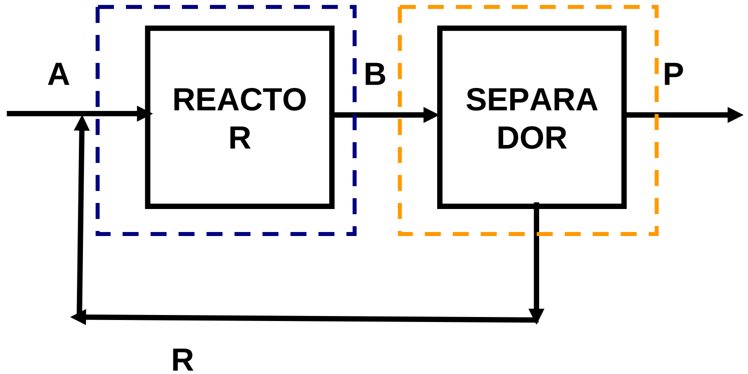
Problema 3: solución

F_A= 1000 kg/h
C_A=200 kg_m/m^3
C_P=5 kg_m/m^3
ρ=1000 g/dm^3
Reacción quimica:

$$(-r_m)=10C_A\left[\frac{kg_m}{m^3\ h}\right]$$

a) F_R
b) C_B



Incógnitas: F_B, F_R, F_P, C_B, C_R
Conocidos: F_A; C_A; C_P; ρ

REACTOR

B.M. Total

$$F_A + F_R = F_B \qquad \left[\frac{kg}{h}\right] \qquad (1)$$

B.M. Parcial (sustancia m)

$$F_A\left[\frac{kg}{h}\right]C_A\left[\frac{kg_m}{m^3}\right]\frac{1}{\rho_A}\left[\frac{m^3}{kg}\right]+F_RC_R\frac{1}{\rho_R}-(-r_m)\left[\frac{kg_m}{m^3\ h}\right]V\left[m^3\right]=F_BC_B\frac{1}{\rho_B} \qquad \left[\frac{kg_m}{h}\right] \qquad (2)$$

SISTEMA SEPARACIÓN

B.M. Total

$$F_B = F_R + F_P \qquad \left[\frac{kg}{h}\right] \qquad (3)$$

B.M. Parcial (sustancia m)

$$F_BC_B\frac{1}{\rho_B}=F_RC_R\frac{1}{\rho_R}+F_PC_P\frac{1}{\rho_P} \qquad \left[\frac{kg_m}{h}\right] \qquad (4)$$

CONDICIONES OPERACIÓN

$$C_R = 10C_P \qquad \left[\frac{kg_m}{m^3}\right] \qquad (5)$$

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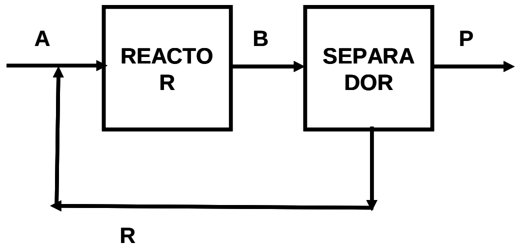

$$F_A + F_R = F_B \qquad \left[\frac{kg}{h}\right] \qquad (1)$$

$$F_A C_A \frac{1}{\rho_A} + F_R C_R \frac{1}{\rho_R} - (-r_m)V = F_B C_B \frac{1}{\rho_B} \qquad \left[\frac{kg_m}{h}\right] \qquad (2)$$

$$F_B = F_R + F_P \qquad \left[\frac{kg}{h}\right] \qquad (3)$$

$$F_B C_B \cancel{\frac{1}{\rho_B}} = F_R C_R \cancel{\frac{1}{\rho_R}} + F_P C_P \cancel{\frac{1}{\rho_P}} \qquad \left[\frac{kg_m}{h}\right] \qquad (4)$$

$$C_R = 10 C_P \qquad \left[\frac{kg_m}{m^3}\right] \qquad (5)$$

Incógnitas: F_B, F_R, F_P, C_B, C_R

Conocidos: F_A; C_A; C_P; ρ

Tomar dos ecuaciones con mismas incognitas y simplificar:

(4) y (5) $\qquad F_B C_B = F_R 10 C_P + F_P C_P \qquad (6)$

(3) y (6) $\qquad (F_R + F_P) C_B = F_R 10 C_P + F_P C_P \qquad (7)$

Incógnitas: F_B, F_R, F_P, C_B, C_R

Por otro lado:

(1) y (2) $\qquad F_A C_A + F_R C_R - (-r_m)V\rho = (F_A + F_R) C_B \qquad (8)$

(8) y (5) $\qquad F_A C_A + F_R 10 C_P - 10 C_B V\rho = (F_A + F_R) C_B \qquad (9)$

Incógnitas: F_B, F_R, F_P, C_B, C_R

(1) y (3) $\qquad F_A = F_P \qquad (10)$

(7) y (10) $\qquad (F_R + F_A) C_B = F_R 10 C_P + F_A C_P \qquad (11)$

Incógnitas: F_R, C_B

(9) $\qquad F_A C_A + F_R 10 C_P = (10 V\rho + F_A + F_R) C_B \qquad (9)$

Incógnitas: F_R, C_B

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(7) y (10) $$(F_R + F_A)C_B = F_R 10 C_P + F_A C_P \qquad (11)$$ Incógnitas: F_R, C_B

$$F_A C_A + F_R 10 C_P = (10 V\rho + F_A + F_R) C_B \qquad (9)$$ Incógnitas: F_R, C_B

(11) re-escrita:

$$C_B = \frac{F_R 10 C_P + F_A C_P}{(F_R + F_A)} \qquad \left[\frac{kg_m}{m^3}\right] \qquad (11)$$

(11) y (9) $$F_A C_A + F_R 10 C_P = (10 V\rho + F_A + F_R)\frac{F_R 10 C_P + F_A C_P}{(F_R + F_A)} \qquad (12)$$

Resolviendo:

$$1000 \cdot 200 + F_R 10 \cdot 5 = (10 \cdot 1 \cdot 1000 + 1000 + F_R)\frac{(F_R 10 \cdot 5 + 1000 \cdot 5)}{(F_R + 1000)} \qquad \left[\frac{kg_m}{h}\right]$$

$$(1000 \cdot 200 + F_R 10 \cdot 5)(F_R + 1000) = (10 \cdot 1 \cdot 1000 + 1000 + F_R)(F_R 10 \cdot 5 + 1000 \cdot 5)$$

$$(2 \cdot 10^5 + 50 F_R)(F_R + 1000) = (11000 + F_R)(50 F_R + 5000)$$

$$(2 \cdot 10^5 F_R + 2 \cdot 10^8 + \cancel{50 F_R^2} + 5 \cdot 10^4 F_R) = (5{,}5 \cdot 10^5 F_R + 5{,}5 \cdot 10^7 + \cancel{50 F_R^2} + 5000 F_R)$$

$$1{,}45 \cdot 10^8 = 3{,}04 \cdot 10^4 F_R$$

$$F_R = 475{,}4 \qquad \left[\frac{kg}{h}\right]$$

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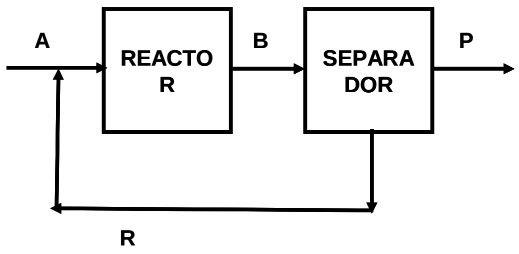


$$F_R = 475,4 \quad \left[\frac{kg}{h}\right]$$

(11) ecuación

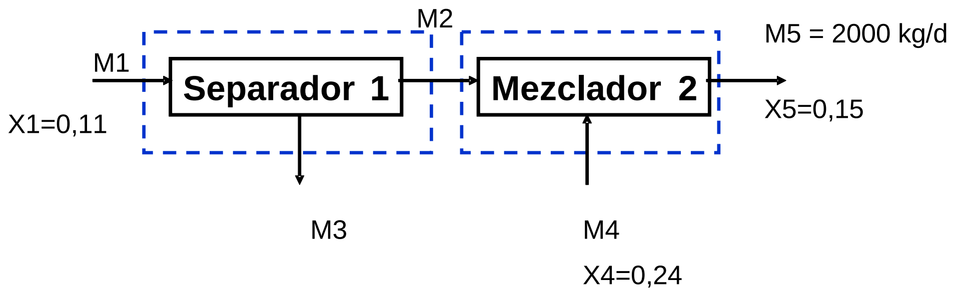
$$C_B = \frac{F_R 10 C_P + F_A C_P}{\left(F_R + F_A\right)} \quad \left[\frac{kg_m}{m^3}\right]$$

$$C_B = \frac{475,4 \cdot 10 \cdot 5 + 1000 \cdot 5}{\left(475,4 + 1000\right)}$$

$$C_B = 19,5 \quad \left[\frac{kg_m}{m^3}\right]$$

Problema 4: solución

a) M4
b) X_{M2}, X_{M3}?



SEPARADOR-1

B.M. Total $$M1 = M2 + M3 \quad \left[\frac{kg}{dia}\right] \qquad (1)$$

B.M. Parcial (sólidos) $$M1\left[\frac{kg}{dia}\right]\cdot X_{M1}\left[\frac{kg_{solid}}{kg}\right] = M2\cdot X_{M2} + M3\cdot X_{M3} \quad \left[\frac{kg_{solido}}{dia}\right] \qquad (2)$$

Condición de diseño $$\frac{M3}{M2} = 1/4 \qquad (3)$$

SEPARADOR-2

B.M.Total $$M2 + M4 = M5 \quad \left[\frac{kg}{dia}\right] \qquad (4)$$

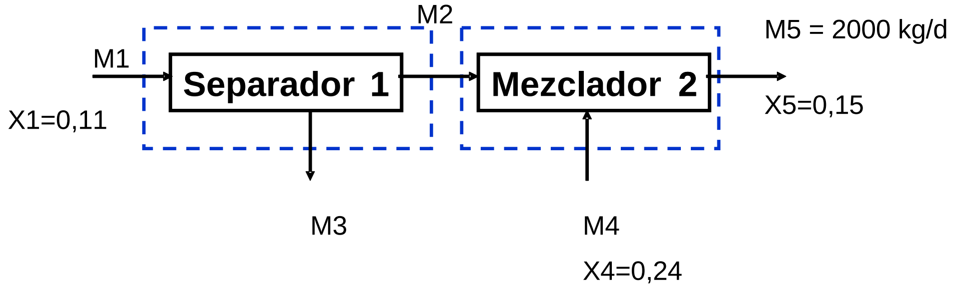
B.M. Parcial (sólidos) $$M2\left[\frac{kg}{dia}\right]\cdot X_{M2}\left[\frac{kg_{solid}}{kg}\right] + M4\cdot X_{M4} = M5\cdot X_{M5} \quad \left[\frac{kg_{solido}}{dia}\right] \qquad (5)$$

Condición de diseño $$M2 = M4 \quad \left[\frac{kg}{dia}\right] \qquad (6)$$

Hemos deducido SEIS ecuaciones a partir de los balances de materia y condiciones de diseño. Contienen también seis incógnitas (M1,M2,M3,M4,X2,X3), por tanto, el sistema de ecuaciones tiene solución.

a) M4

b) X_{M2}, X_{M3}?



(3) $\frac{M3}{M2} = \frac{1}{4} \longrightarrow M_2 = 4M_3$

(1) $M_1 = 4M_3 + M_3 \left[\frac{kg}{dia}\right]$

$\longrightarrow M_1 = 5M_3 \left[\frac{kg}{dia}\right]$

(4) $M_2 + M_4 = M_5$

(6) $M2 = M4 \left[\frac{kg}{dia}\right]$

$\longrightarrow M_2 + M_2 = 2000 \qquad \underline{\underline{M_2 = M_4}} = 1000 \left[\frac{kg}{dia}\right]$

(5) $1000\left[\frac{kg}{dia}\right] \cdot X_{M2}\left[\frac{kg_{solid}}{kg}\right] + 1000 \cdot 0,24 = 2000 \cdot 0,15 \left[\frac{kg_{solido}}{dia}\right] \qquad \underline{\underline{X_{M2}}} = 0,06\left[\frac{kg_{solid}}{kg}\right]$

(3) $M_2 = 4M_3 \qquad M_3 = \frac{M_2}{4} = 250 \left[\frac{kg}{dia}\right]$

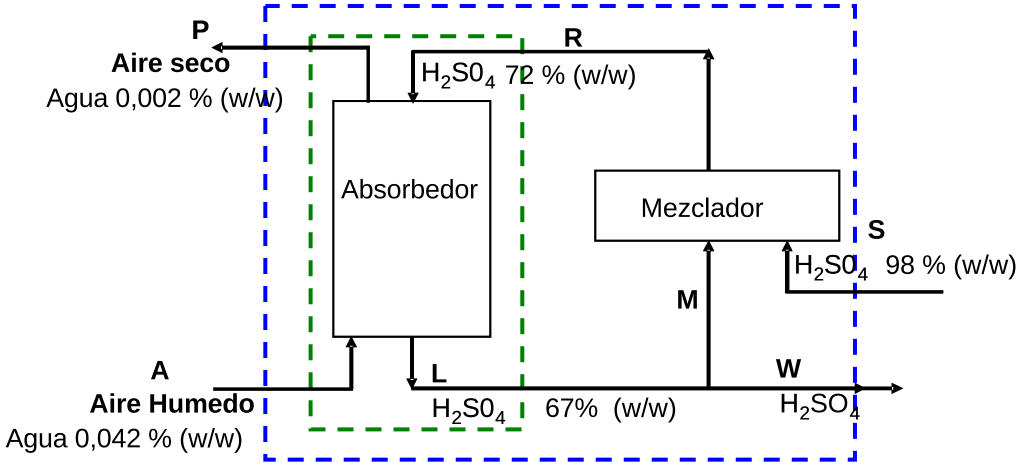
(1) $M_1 = 5M_3 \qquad M_1 = 5 \cdot 250 = 1250 \left[\frac{kg}{dia}\right]$

(2) $1250\left[\frac{kg}{dia}\right] \cdot 0,11\left[\frac{kg_{solid}}{kg}\right] = 1250 \cdot 0,06 + 250 \cdot X_{M3} \left[\frac{kg_{solido}}{dia}\right] \qquad \underline{\underline{X_{M3}}} = 0,31\left[\frac{kg_{solid}}{kg}\right]$

Problema 5: solución

a) S
b) $W \cdot X_W$ $\left[\frac{kg_{sulfurico}}{h}\right]$

A=150 kg/h



Sistema azul: toda la planta

B.M. Total $$A + S = W + P \qquad \left[\frac{kg}{h}\right] \qquad (1)$$

B.M. Parcial (Sulfúrico) $$S\left[\frac{kg}{h}\right] X_{s,sulf}\left[\frac{kg_{Sulfd}}{kg}\right] = W \cdot X_{W,sulf} \qquad \left[\frac{kg_{sulfurico}}{h}\right] \qquad (2)$$

Ecuaciones (1) y (2) incognitas son S, W y P. Por tanto, podemos resover si logramos otra ecuación adicional que contenga estas mismas variables.

Sistema verde: torre absorción (o sistema azul)

B.M. Parcial (Aire) $$A\left[\frac{kg}{h}\right] X_{A,Aire}\left[\frac{kg_{Aire}}{kg}\right] = P \cdot X_{P,Aire} \qquad \left[\frac{kg_{Aire}}{h}\right] \qquad (3)$$

Ecuación (3) única incógnita es P. Por tanto, tenemos 3 ecuaciones y 3 incógnitas. Podemos resolver.

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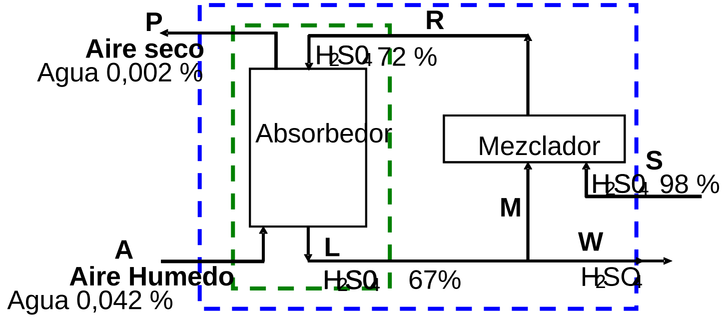
a) S
b) $W \cdot X_W \left[\frac{kg_{sulfuriko}}{h}\right]$



B.M. Total

$$A + S = W + P \quad \left[\frac{kg}{h}\right] \qquad (1)$$

B.M. Parcial (Sulfúrico)

$$S\left[\frac{kg}{h}\right] X_{s,sulf}\left[\frac{kg_{Sulfd}}{kg}\right] = W \cdot X_{W,sulf} \quad \left[\frac{kg_{sulfurico}}{h}\right] \qquad (2)$$

B.M. Parcial (Aire)

$$A\left[\frac{kg}{h}\right] X_{A,Aire}\left[\frac{kg_{Aire}}{kg}\right] = P \cdot X_{P,Aire} \quad \left[\frac{kg_{Aire}}{h}\right] \qquad (3)$$

SOLUCIÓN:

(3) $$150\left[\frac{kg}{h}\right](1-0{,}00042)\left[\frac{kg_{Aire}}{kg}\right] = P(1-0{,}00002) \qquad P = 149{,}94 \left[\frac{kg}{h}\right]$$

(1) $$150\left[\frac{kg}{h}\right] + S = W + 149{,}94 \qquad S = W - 0{,}06 \left[\frac{kg}{h}\right]$$

(2) $$(W - 0{,}06)0{,}98 = W \cdot 0{,}67 \qquad W = 0{,}19 \left[\frac{kg}{h}\right]$$

Finalmente $S = 0{,}19 - 0{,}06$ $\qquad S = 0{,}13 \left[\frac{kg}{h}\right]$

b) $W \cdot X_W$

$$W\left[\frac{kg}{h}\right] X_{W,sulf}\left[\frac{kg_{Sulfd}}{kg}\right] = 0{,}19 \cdot 0{,}67 \qquad W\left[\frac{kg}{h}\right] X_{W,sulf}\left[\frac{kg_{Sulfd}}{kg}\right] = 0{,}127 \left[\frac{kg_{sulfúrico}}{h}\right]$$

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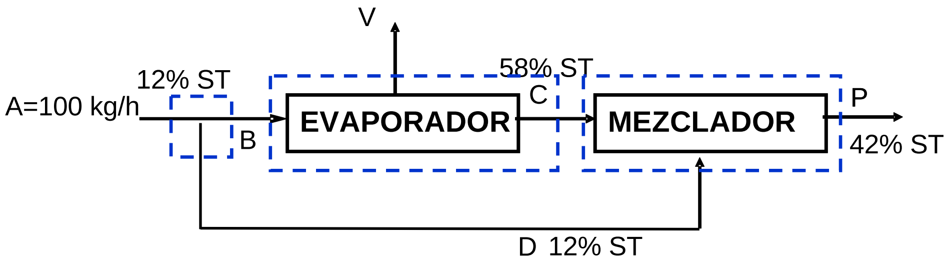
Problema 6: solución

b) P [kg/h]
c) V [kg/h]
d) $P \cdot X_P$ [kgsolid/h]



Tenemos 5 incognitas (B, C, D, V, P), por tanto, necesitamos 5 ecuaciones.

SISTEMA 1: BIFURCACIÓN

B.M. Total $$A = B + D \quad \left[\frac{kg}{h}\right] \qquad (1)$$

SISTEMA 2: EVAPORADOR

B.M. Total $$B = C + V \quad \left[\frac{kg}{h}\right] \qquad (2)$$

B.M. Parcial sólidos $$B\left[\frac{kg}{h}\right] X_B \left[\frac{kg_{solid}}{kg}\right] = C \cdot X_C + V \cdot X_V \quad \left[\frac{kg_{solid}}{h}\right] \qquad (3)$$

SISTEMA 3: MEZCLADOR

B.M. Total $$C + D = P \quad \left[\frac{kg}{h}\right] \qquad (4)$$

$$C\left[\frac{kg}{h}\right] X_C \left[\frac{kg_{solid}}{kg}\right] + D \cdot X_D = P \cdot X_P \quad \left[\frac{kg_{solid}}{h}\right] \qquad (5)$$

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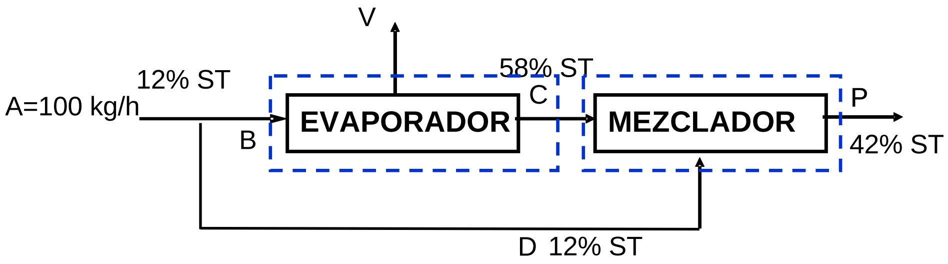

b) P [kg/h]
c) V [kg/h]
d) $P \cdot X_P$ [kgsolid/h]

Resolvemos el sistema de ecuaciones (1) – (5):

(1) $$100 = B + D \quad \left[\frac{kg}{h}\right]$$

(2) $$B = C + V \quad \left[\frac{kg}{h}\right]$$

(3) $$B\left[\frac{kg}{h}\right]0{,}12\left[\frac{kg_{solid}}{kg}\right] = C \cdot 0{,}58 + V \cdot 0 \quad \left[\frac{kg_{solid}}{h}\right]$$

(4) $$C + D = P \quad \left[\frac{kg}{h}\right]$$

(5) $$C\left[\frac{kg}{h}\right]0{,}58\left[\frac{kg_{solid}}{kg}\right] + D \cdot 0{,}12 = P \cdot 0{,}42 \quad \left[\frac{kg_{solid}}{h}\right]$$

(1) y (2) (6) $$100 = C + V + D \quad \left[\frac{kg}{h}\right]$$

(3) y (2) (7) $$0{,}12 \cdot C + 0{,}12 \cdot V = C \cdot 0{,}58 + V \cdot 0 \qquad C = 0{,}26 \cdot V \left[\frac{kg}{h}\right]$$

(5) y (4), (7) (8) $$0{,}58 \cdot C + 0{,}12 \cdot D = 0{,}42 \cdot C + 0{,}42 \cdot D \qquad D = 0{,}14 \cdot V \left[\frac{kg}{h}\right]$$

(6) y (7), (8) (9) $$100 = 0{,}26 \cdot V + V + 0{,}14 \cdot V \qquad \underline{\underline{V = 71{,}47}} \left[\frac{kg}{h}\right] \longrightarrow \begin{array}{l} C = 18{,}6 \\ D = 10 \end{array} \left[\frac{kg}{h}\right]$$

$$P = C + D = 18{,}6 + 10 = \underline{\underline{28{,}6}}$$

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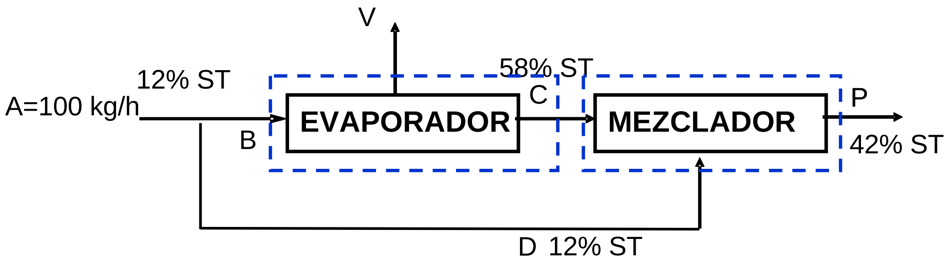
b) P [kg/h]
c) V [kg/h]
d) $P \cdot X_P$ [kgsolid/h]



Finalmente,

$$P = C + D = 18{,}6 + 10 = 28{,}6 \quad \left[\frac{kg}{h}\right]$$

$$X_P = 0{,}42\left[\frac{kg_{solid}}{kg}\right]$$

$$P \cdot X_P = 28{,}6\left[\frac{kg}{h}\right]0{,}42\left[\frac{kg_{solid}}{kg}\right] = 288\left[\frac{kg_{solid}}{día}\right]$$

Nota: observad que el problema se resuelve fácilmente si elegimos un sistema alternativo. Puesto que B, C y D no son variables de interés, podemos elegir como sistema toda la planta, de tal forma que las variables anteriores no aparecen. Tenemos dos ecuaciones y dos incógnitas. Resolvemos.

$$100 = V + P \quad \left[\frac{kg}{h}\right]$$

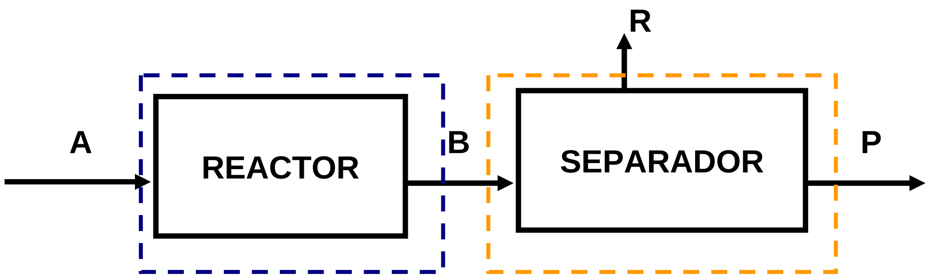
$$100\left[\frac{kg}{h}\right]0{,}12\left[\frac{kg_{solid}}{kg}\right] = P \cdot 0{,}42 + V \cdot 0 \quad \left[\frac{kg_{solid}}{h}\right]$$

$$P = \frac{100 \cdot 0{,}12}{0{,}45} = 28{,}6 \quad \left[\frac{kg}{h}\right]$$

Problema 15: solución

F_A= 1000 kg/h
C_A= 183 kg_r/m^3
C_P= 2,5 kg_r/m^3
ρ_A= 0,915 g/dm³; $\rho_{B,R,P}$= 1,0 g/dm³
V=1500 L
Condición operación $C_R=10C_P$
$(-r_r)=130 \left[\frac{kg_r}{m^3\ h}\right]$

a) R
b) C_B



Incógnitas: B, R, P, C_B, C_R
Conocidos: A; C_A; C_P; ρ

REACTOR

B.M. Total

$$A = B \quad \left[\frac{kg}{h}\right] \qquad (1)$$

B.M. Parcial (sustancia r)

$$A\left[\frac{kg}{h}\right]C_A\left[\frac{kg_r}{m^3}\right]\frac{1}{\rho_A}\left[\frac{m^3}{kg}\right]-(-r_r)\left[\frac{kg_r}{m^3\ h}\right]V\left[m^3\right]=B\cdot C_B\frac{1}{\rho_B}\left[\frac{kg_r}{h}\right] \qquad (2)$$

SISTEMA SEPARACIÓN

B.M. Total

$$B = R + P \quad \left[\frac{kg}{h}\right] \qquad (3)$$

B.M. Parcial (sustancia r)

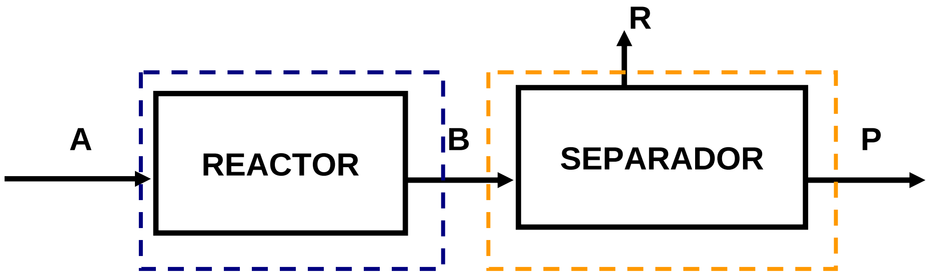
$$B\left[\frac{kg}{h}\right]C_B\left[\frac{kg_r}{m^3}\right]\frac{1}{\rho_B}\left[\frac{m^3}{kg}\right]-R\cdot C_R\frac{1}{\rho_R}=P\cdot C_P\frac{1}{\rho_P} \quad \left[\frac{kg_r}{h}\right] \qquad (4)$$

CONDICIONES OPERACIÓN

$$C_R = 10C_P \quad \left[\frac{kg_r}{m^3}\right] \qquad (5)$$

F_A= 1000 kg/h
C_A= 183 kg_r/m^3
C_P= 2,5 kg_r/m^3
ρ_A= 0,915 g/dm³; $\rho_{B,R,P}$= 1,0 g/dm³
V=1500 L
Condición operación $C_R=10C_P$
$(-r_r)=130 \left[\frac{kg_r}{m^3\ h}\right]$

a) R
b) C_B



Incógnitas: B, R, P, C_B, C_R
Conocidos: A; C_A; C_P; ρ

Resolviendo el conjunto de ecuaciones (1) a (5):

(1) $$B = 1000 \quad \left[\frac{kg}{h}\right]$$

(2) $$1000\left[\frac{kg}{h}\right]183\left[\frac{kg_r}{m^3}\right]\frac{1}{915}\left[\frac{m^3}{kg}\right]-130\left[\frac{kg_r}{m^3\ h}\right]1{,}5\left[m^3\right]=1000\cdot C_B\frac{1}{1000} \qquad C_B = 5 \left[\frac{kg_r}{m^3}\right]$$

(5) $$C_R = 10\cdot 2{,}5 = 25 \left[\frac{kg_r}{m^3}\right]$$

(4) $$1000\left[\frac{kg}{h}\right]5\left[\frac{kg_r}{m^3}\right]\frac{1}{1000}\left[\frac{m^3}{kg}\right]-R\cdot 25\frac{1}{1000}=P\cdot 2{,}5\frac{1}{1000} \qquad \left[\frac{kg_r}{h}\right]$$

(3) $$1000 = R + P \quad \left[\frac{kg}{h}\right]$$

$$1000\left[\frac{kg}{h}\right]5\left[\frac{kg_r}{m^3}\right]\frac{1}{1000}\left[\frac{m^3}{kg}\right]-R\cdot 25\frac{1}{1000}=\left(1000-R\right)\cdot 2{,}5\frac{1}{1000} \qquad R = 111{,}1 \left[\frac{kg}{h}\right]$$

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