Transport Processes and Separation Process Principles 5th edition Geankoplis Solutions Manual

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Instructor Manual for

Transport Processes and Separation Process Principles

Fifth Edition

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Publisher's Note: This Instructor Manual is a work in process. Any pages without a supplied solution will be replaced at future releases.

(1.2-1)

Eq. (1.3-4) $k = 353.2 = °C + 273.15 \quad °C = 80.05 = \boxed{80\,°C}$

Eq. (1.3-2) $°C = 80.0 = (1/1.8)(°F - 32) \quad °F = \boxed{176\,°F}$

Eq. (1.3-3) $°R = °F + 460 = 176 + 460 \quad °R = \boxed{636\,°R}$

(1.2-2)

Eq. (1.3-2) $°\mathrm{C} = (1/1.8)(°\mathrm{F} - 32) = (1/1.8)(155 - 32) = \boxed{68.33\,°\mathrm{C}}$

Eq. (1.3-4) $\mathrm{K} = °\mathrm{C} + 273.15 = 68.33 + 273.15 = \boxed{341.5\,\mathrm{K}}$

Eq. (1.3-3) $°\mathrm{R} = °\mathrm{F} + 460 = 155 + 460 = \boxed{615\,°\mathrm{R}}$

(1.3-1)

$$\text{MW}(\text{O}_2) = 32.00, \quad \text{MW}(\text{N}_2) = 28.02$$

$$\text{MW}(\text{air}) = 0.21(32.00) + 0.79(28.02) = \boxed{28.9\,\text{kg}/\text{kg mol}}$$

(1.3-2)

$$\underset{\text{MW }28.01}{2CO} + \underset{32.00}{O_2} \rightarrow \underset{44.01}{2CO_2} \quad \text{moles CO} = \frac{56.0\,\text{kg}}{28.01\,\text{kg/kg mol}} = 2.00\,\text{kg mol}$$

$$\text{moles } O_2 = 1.00, \quad 1.00(32.00) = \boxed{32.0\,\text{kg } O_2} \quad 2.00(44.0) = \boxed{88.0\,\text{Kg } CO_2}$$

(1.3-3)

Gas	g	MW	g mol	mol/sec
N_2	20	28.02	0.7138	0.1648 mol/sec
O_2	83	32.00	2.5938	0.5990
CO_2	45	44.01	1.0225	0.2362
Total	148 g		4.330/g mol	1.0000

$$\text{Average mol wt} = \frac{148\,\text{g}}{4.3301\,\text{g mol}} = \boxed{\begin{array}{l} 34.2\,\text{g/g mol} \\ 34.2\,\text{kg/kg mol} \end{array}}$$

(1.3-4)

(1.3-5)

(1.4-1)

$P = 2.4$ mm Hg

From Appendix A.1

1 atm = 760 mm Hg

$$P = \frac{2.4\,\text{mm Hg}}{760\,\text{mm Hg/atm}} = \boxed{3.16 \times 10^{-3}\,\text{atm}}$$

1 atm = 33.90 × 12 in. H_2O (at 4°C)

$$P = \frac{2.4}{760}\,\text{atm}\left(33.90 \times 12\,\frac{\text{in.}\,H_2O}{\text{atm}}\right) = \boxed{1.285\,\text{in.}\,H_2O}$$

1 μm = 10^{-3} mm

$$P = \frac{2.4\,\text{mm}}{10^{-3}\,\text{mm/μm}} = \boxed{2,400\,\text{μm Hg}}$$

1 atm = 1.01325×10^5 Pa

$$P = \frac{2.4}{760}\,\text{atm}\left(1.01325 \times 10^5\,\frac{\text{Pa}}{\text{atm}}\right) = \boxed{320\,\text{Pa}}$$

(1.4-2)

$V_1 = 65.0$ ft^3, $T_1 = 460 + 90 = 550$ °R, $T_2 = 460 + 65 = 525$ °R

From Appendix A.1, 1 atm = 14.696 psia

$p_1 = 29.0 + 14.696 = 43.696$ psia, $p_2 = 75.0 + 14.696 = 89.696$ psia

$p_1 = 43.696/14.696 = 2.975$ atm, $p_2 = 89.696/14.696 = 6.104$ atm

Eq. (1.4-2)

$$V_2 = V_1 \frac{p_1}{p_2} = 65.0 \frac{(2.975)}{(6.104)} = \boxed{30.24\,\text{ft}^3}$$

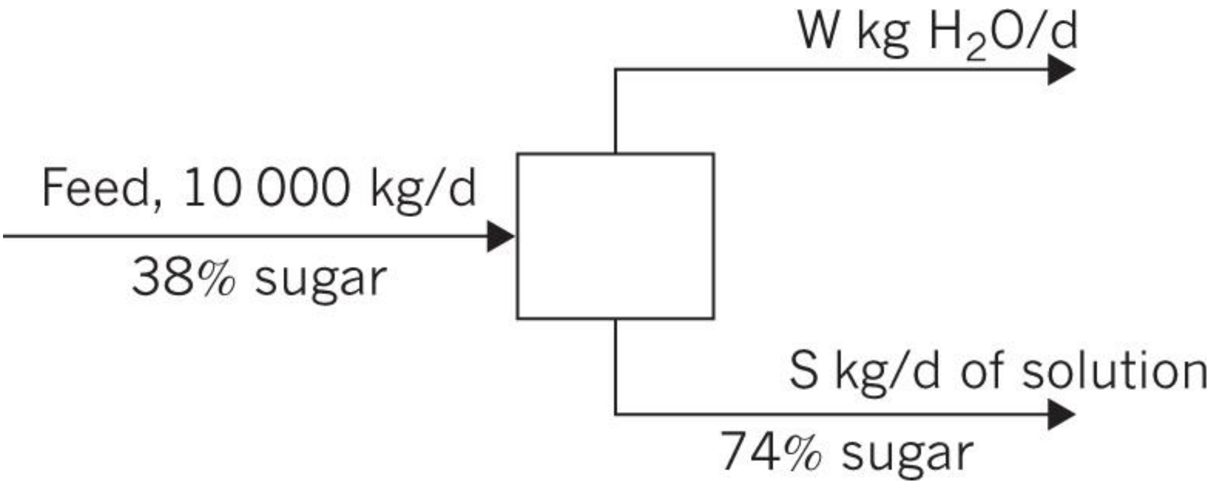
$R = 0.7302$ ft^3 · atm/lb mol · °R, MW of $N_2 = 28.01$

Eq. (1.4-1)

$$n = pV/RT = (2.975)(65.0)/(0.7302)(550) = \boxed{0.4815\,\text{lb mol}}$$

Density, $$= (0.4815)(28.01)/30.24 = \boxed{0.446\,\text{lb}_m/\text{ft}^3}$$

(1.5-1)



Basis: 10 000 kg/a feed

Total balance

$$10\,000 = S + W$$

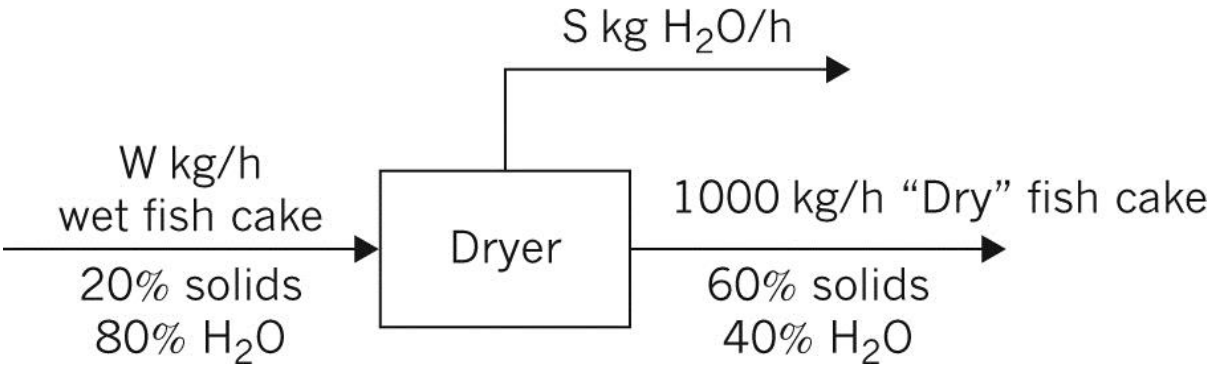
Solids balance

$$0.38\ (10\,000) = 0.745 + (0)W$$

$$W = 10000 - 5135 = \boxed{4865\ \text{kg}\ H_2O/d}$$

$$\boxed{S = 5135\ \text{kg/d of } 74\%\ \text{solution}}$$

(1.5-2)



Basis: 1000 kg/h "dry" fish cake

Solids balance

$$0.20\,W = S(0) + 0.60(1000)$$
$$\boxed{W = 3000\,\text{kg/h wet cake feed}}$$

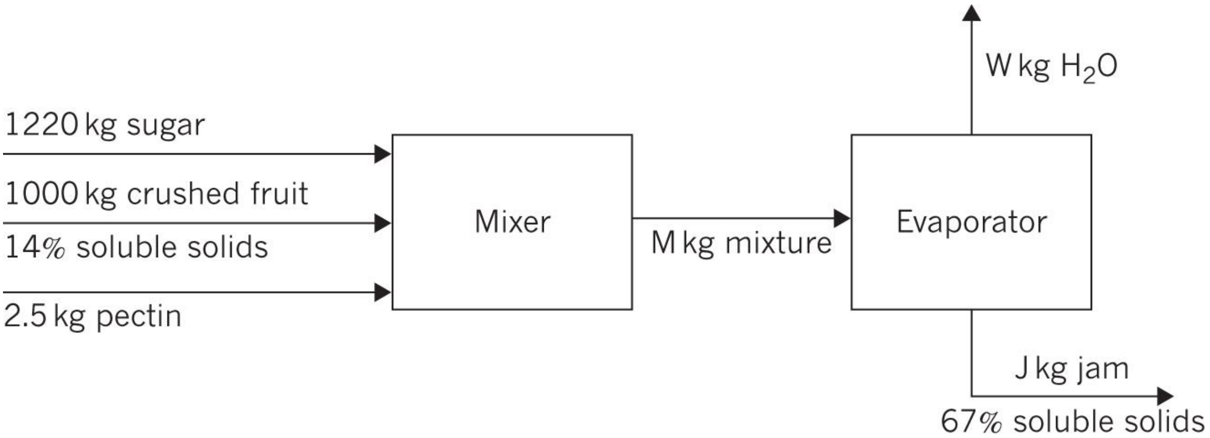
Total balance

$$W = S + 1000$$
$$3000 = S + 1000$$
$$\boxed{S = 2000\,\text{kg}\;H_2O/\text{h}}$$

(1.5-3)

(1.5-4)

(1.5-5)



Basis: 1000 kg crushed fruit

Soluble solids balance over whole process

$$1220 + 0.14(1000) + 2.5 = 0.67J + W(0)$$

$$\boxed{J = 2033.5 \text{ kg jam}}$$

Total balance over mixer

$$1220 + 1000 + 2.5 = M$$

$$\boxed{M = 2222.5 \text{ kg mixture}}$$

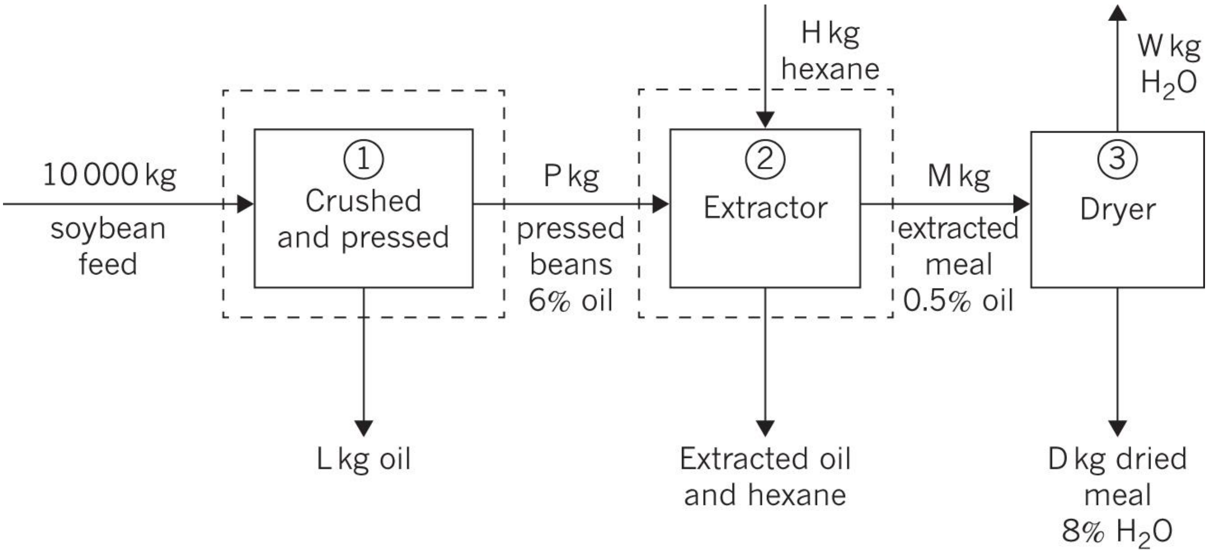
Total balance over evaporator

$$2222.5 = W + 2033.5$$

$$\boxed{W = 189 \text{ kg } H_2O}$$

(1.5-6)

(1.5-7)



Soybean feed

	%	kg	
Oil	18.0	1800	
Protein	35.0	3500	meal
Carbohydrate	27.1	2710	meal
Fiber, ash	9.4	940	meal
Moisture	10.5	1050	meal
	100.0	10,000	

(a) Balance on meal (1)

$$0.82(10000) = 0.94P \quad \boxed{P = 8723\,\text{kg dressed beans}} \quad L = 1277\,\text{kg oil}$$

Total balance

$$10{,}000 = L + P$$

(b) Balance on meal (2)

$$0.94(8723) = 0.995M \quad \boxed{M = 8241\,\text{kg extracted meal}}$$

kg oil = 0.005(8241) = 41 kg oil in meal

(c) Composition of M

Oil 41 kg

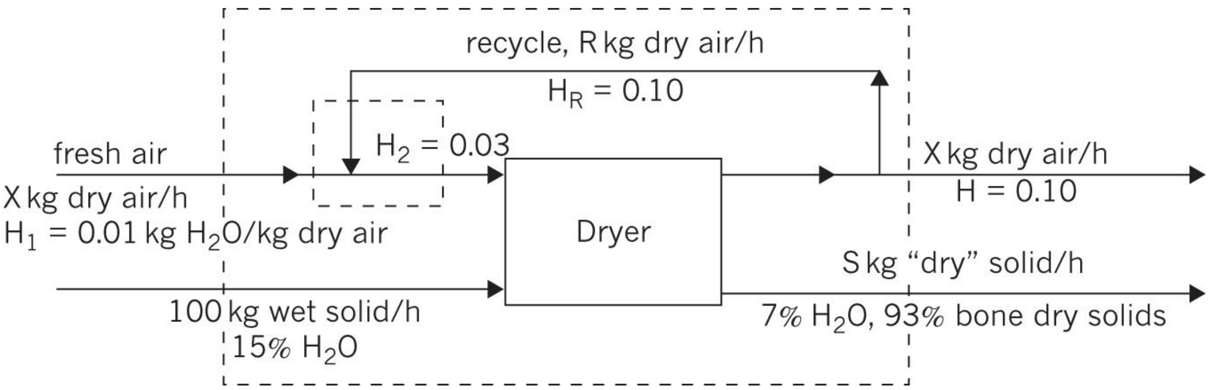
Protein	3500
Carbohydrate	2710
Fiber, ash	940
H_2O	1050
	M = 8241 kg

Balance on meal (less H_2O) (3)

$$8241 - 1050 = 0.92\,D \qquad \boxed{D = 7816\,\text{kg dried meal}}$$

$$\text{Wt\%} = \frac{3500}{7816} \times 100 = \boxed{44.8\,\text{wt \% protein}}$$

(1.5-8)



Basis: 100 kg wet solid/h

Bone dry solids balance on overall process

$$0.85(100) = 0.93S \qquad \boxed{S = 91.4\,\text{kg/h "dried" product}}$$

Water balance on overall process

$$0.01x + 0.15(100) = 0.10x + 0.07(91.4)$$

$$\boxed{x = 95.6\,\text{kg/h dry air in fresh air}}$$

Water balance on inlet point

$$0.01X + 0.10R = 0.03(R + X)$$

$$0.01(95.6) + 0.10R = 0.03(R + 95.6)$$

$$\boxed{R = 27.3\,\text{kg/h dry air in recycle air}}$$

Overall check balance on H_2O

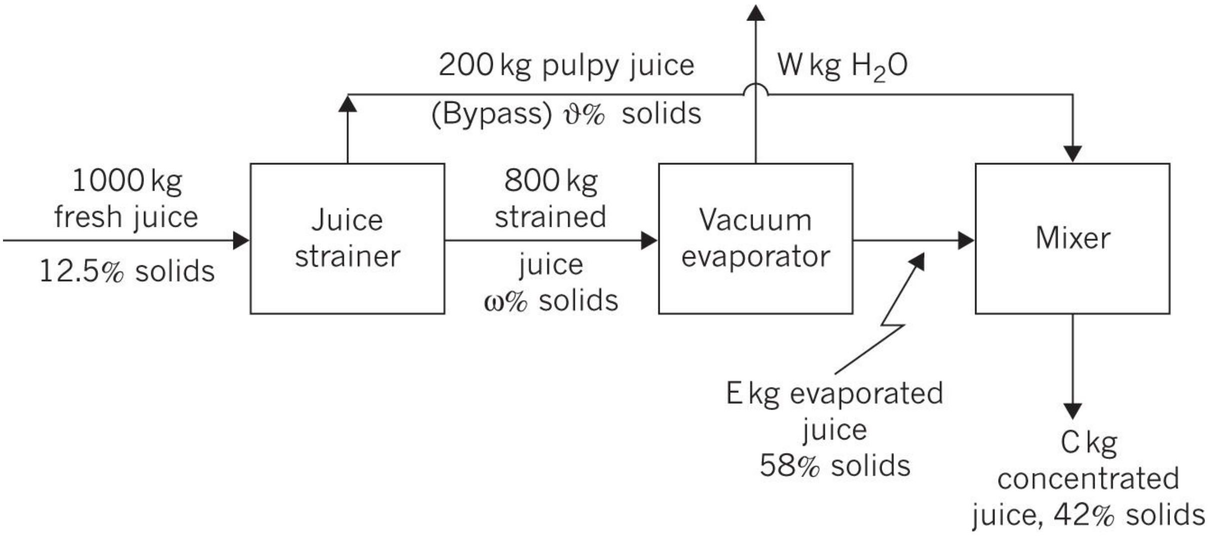
$$0.01(95.6) + 0.15(100) = 0.07(91.4) + 0.10(95.6)$$

$$0.956 + 15.00 = 6.40 + 9.56$$

$$15.956 \cong 15.96 \text{ Hence, a close check.}$$

(1.5-9)

(1.5-10)



Basis: 1000 kg fresh juice

Total balance on overall process

$1000 = W + C$

Solids balance on overall process

$0.125(1000) = W(0) + 0.42\ C$

$W = 1000 - 298$

$W = 702$ kg H_2O

$\boxed{C = 298\,\text{kg concentrated juice}}$

Balance on evaporator

Total

$800 = 702 + E$

$E = 98$ kg evaporated juice

Solids

$$\frac{w}{100}(800) = 702(0) + 0.58(98)$$

$\boxed{w = 7.10\%\ \text{solids in strained juice}}$

Solids balance on mixer

$$\frac{v}{100}(200)+0.58\overset{(E)}{(98)}=0.42\overset{(C)}{(298)}$$

$$\boxed{v = 34.2\%\ \text{solids in pulpy juice by passed}}$$

(1.5-11)

(1.5-12)

(1.5-13)

(1.5-14)

(1.6-1)

$$g\,\text{mol}\,CO_2 = \frac{250}{44.0} = 5.680$$

$$c_{km}\left(298-373\,K\right) = 38.73\,\text{kJ/kg}\,\text{mol}\cdot K \quad \text{Table1.5}-1$$

$$\left(298-373\,K\right) = 38.73$$

$$q\left(373-623\,K\right) = q_1\left(298-623\right) - q_2\left(298-373\right)$$

$$q = \frac{5.680}{1000}\left[43.06\left(623-298\right) - 38.73\left(373-298\right)\right]$$

$$\boxed{q = 62.98\,\text{kJ}}$$

$$q = \frac{62.98\,\text{kJ}\times 1000}{4.184\,\frac{J}{\text{cal}}} = \boxed{15\,050\,\text{cal}}$$

$$q = \frac{62.98\,\text{kJ}}{1.05506\,\text{kJ/btu}} = \boxed{59.7\,\text{btu}}$$

(1.6-3)

From appendix A.4, $c_k = 4.02$ kJ/kg · K at 32.8 °C

assume $c_{km} = 4.02$ note: (t − 10) °C = (t − 10) K

$$q = 121300\,\text{kJ} = 454\,\text{kg}\left(4.02\,\frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right)(t-10)\,\text{K}$$

solving, $(t-10) = 66.5\,\text{K} = 66.5\,°\text{C}$ $\boxed{t = 76.5\,°\text{C}}$

(1.6-4)

(a) A.2-9 P = 30 psia Liquid H_2O

$$\Delta H = H_{240°F} - H_{40°F}$$
$$= 208.44 - 8.02 = \boxed{200.42 \text{ btu/lb}_m}$$

(b) P = 24.97 psia

$$H_{240°F}(\text{vapor}) = 1160.7$$
$$H_{40°F}(\text{liquid}) = \underline{8.02}$$
$$\boxed{\Delta H = 1152.7 \text{ btu/lb}_m}$$

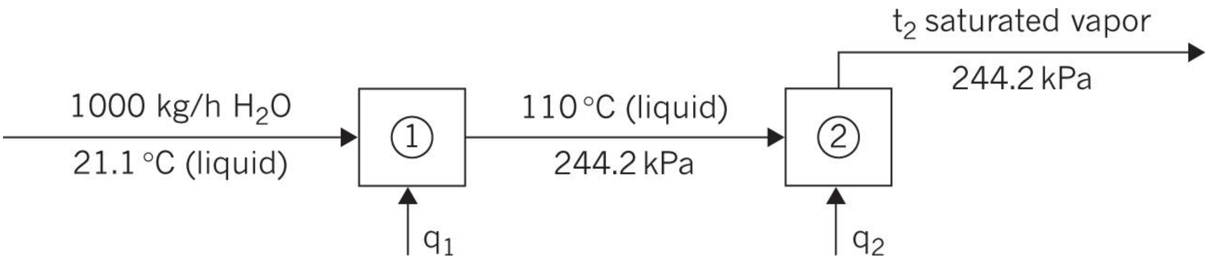
(c) P = 1.0 atm abe

$$H_{212°F}(\text{vapor}) = 1150.5$$
$$H_{40°F}(\text{liquid}) = \underline{28.1}$$
$$\boxed{\Delta H = -1122.4 \text{ btu/lb}_m}$$

(d) P = 1.0 atm abe

$$H_{212°F}(\text{vapor}) = 1150.5$$
$$H_{212°F}(\text{liquid}) = \underline{180.2}$$
$$\boxed{\Delta H = -970.3 \text{btu/lb}_m \left(-2256.9 \text{kJ/kg}\right)}$$

(1.6-5)



From Table A.2–9, t_2 = 126.6 °C (linear interpolation)

h (liq. at 21.1 °C) = 88.56 kJ/kg, h (liq. at 110 °C) = 461.30 kJ/kg

H (sat'd vapor at 126.6 °C) = 2715.7 kJ/kg

First stage (1)

$$q_1 = (461.30 - 88.56\,\text{kJ/kg})\left(1000\,\frac{\text{kg}}{\text{h}}\right) = \boxed{3.7274\times10^5\,\text{kJ/h}}$$

Both stages (1) and (2)

$$q_1 + q_2 = (2715.7 - 88.56)(1000) = \boxed{2.6271\times10^6\ \text{kJ/h}}$$

(1.6-7)

Table A.3–1 (4.0 g mol NH_3)

$$\underset{4(-46.19\,\text{kJ/gmol})}{4\,NH_3(g)} + \underset{5(O)}{5\,O_2(g)} \rightarrow \underset{4(+90.374)}{4\,NO(g)} + \underset{6(-241.826)}{6H_2O(g)}$$

Eq. (1.6-7)

$$\Delta H^o = \sum \Delta H^o_{f(\text{products})} - \sum \Delta H^o_{f(\text{reactants})}$$

$$= \left[4(+90.374) + 6(-241.826)\right] - \left[4(-46.19) + 5(0)\right]$$

$$\boxed{\Delta H^o = -904.7\,\text{kJ/gmol}\left(-216.24\,\text{kcal/gmol}\right)}$$

(1.7-1)

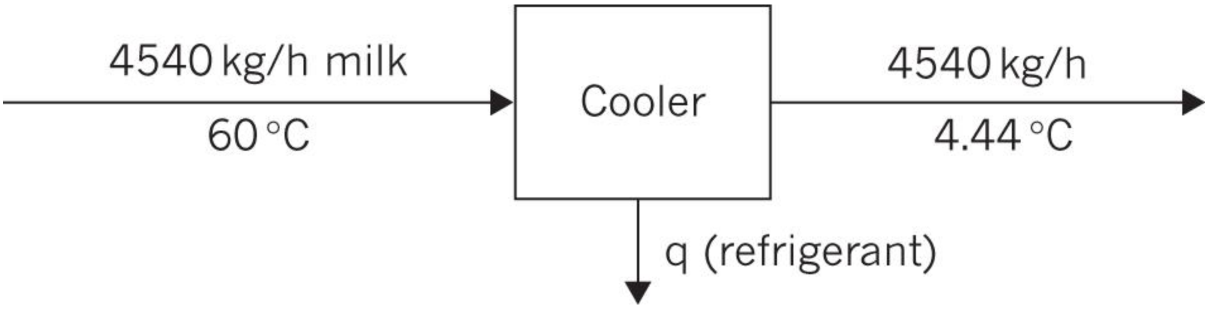


Table A.4–1

C_{km} (milk) = 3.85 kJ/kg · k

Heat balance: Datum=25 °C

Input

H (milk) = 4540 (3.85)(60 − 25) = 611765 kJ/h

Output

H (milk) = 4540 (3.85)(4.44−25) = −359368 kJ/h

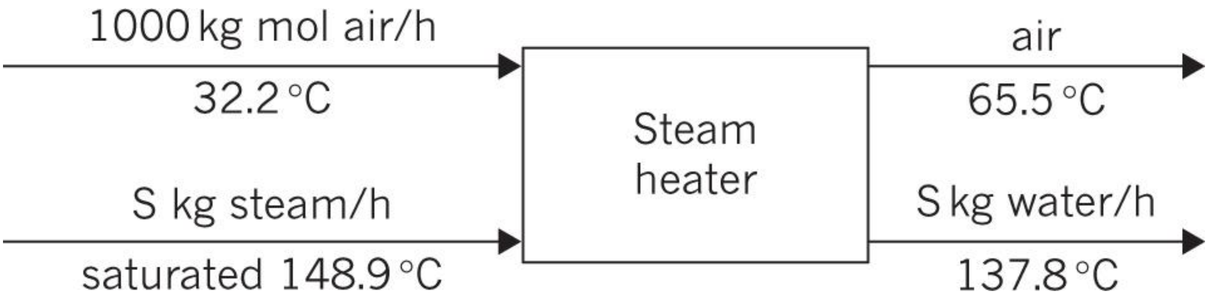
q

Input = Output

611765 = −359368 + q

$$q = 971133\,\text{kJ/h} = \frac{971{,}133}{3600} = \boxed{\begin{array}{l}269{,}6\,\text{kW} \\ (920\,000\,\text{btu/h})\end{array}}$$

(1.7-4)



Datum: 25 °C

(air c_{km} = 29.20 kJ/kg mol · K for 25 − 32.2 °C Table 1.6–1)

Heat in

$$H(\text{air}) = (1000)(29.20)(32.2 - 25.0) \quad = 210\,240 \text{ kJ / h}$$
$$H(\text{steam}) = S\underset{\substack{(\text{Table A.2–9})\\ 148.9°\text{C}}}{(2745.1)} \quad = 2745.15 \text{ kJ / h}$$

Heat out

$$H(\text{air}) = (1000)(29.25)(65.5 - 25.0) \quad = \quad 1184\,625 \text{ kJ/h}$$
$$H(\text{water}) = S\underset{137.8°\text{C}}{(579.70)} \quad = \quad 579.70 S \text{ kJ/h}$$

In = out

210 240 + 2745.15 = 1 184 625 + 57.70 S

$$\boxed{S = 450 \text{ kg steam/h}}$$

(1.8-1)

Simpson's Method

Eq. (1.8-2) $h = 0.1 \qquad m = \frac{b - a}{0.1} = \frac{0.6 - 0}{0.1} = 6$

Eq. (1.8-3)

$$A = \int_{x=0}^{x=0.6} f(x)\,dx = \frac{h}{3}[f_0 + 4(f_1 + f_3 + f_5 + \ldots) + 2(f_2 + f_4 + f_6 + \ldots)]$$

$$A = \frac{0.1}{3}[100 + 4(75 + 53.5 + 60) + 2(60.5 + 53 + 72.5)]$$

$$A = 38.45$$

(1.8-2)

$$\text{Total flow in m}^3 = \int_{t=0}^{t=t_F} q\,dt \qquad \text{Eq. (1.8-1)}$$

where t = min., and q = flow rate m^3/min.

The data of flow note q vs. t are plotted as shown.

(a) For the first 60 min., a series of rectangles are drawn as shown. The total area under the curve is the sum of the rectangles A through F.

$$\begin{aligned}\text{Total area} &= 680(10)+740(10)+805(10)+853(10)\\ &\quad +884(10)+884(10)\\ &= \boxed{48460\,\text{m}^3 \text{ for } 60\,\text{min}.}\end{aligned}$$

For 120 min., use rectangles A through L

$$\begin{aligned}\text{Total area} &= 48,460+840(10)+763(10)+700(10)+650(10)\\ &\quad +620(10)+620(10)\\ &= \boxed{90\,390\,\text{m}^3 \text{ for } 120\,\text{min}.}\end{aligned}$$

(b) Simpson's method

Eq. (1.8-3)

$$h = 10\,\text{min}. \quad m = \frac{b-a}{h} = \frac{120-0}{10} = 12$$

Eq. (1.8-4)

$$\begin{aligned}\int_0^{120} f(x)dx &= \frac{h}{3}\left[h_0 + 4\left(f_1+f_3+f_5+f_7+f_9+\overset{f_{m-1}}{f_{11}}\right)\right.\\ &\quad \left. +2\left(f_2+f_4+f_6+f_8+f_{10}+\overset{f_m}{f_{12}}\right)\right]\\ &= \frac{10}{3}\left[655+4(705+830+890+800+670+620)\right.\\ &\quad \left.+2(780+870+870+725+640+610)\right]\\ &= \boxed{92\,350\,\text{m}^3 \text{ for } 120\,\text{min}}\end{aligned}$$