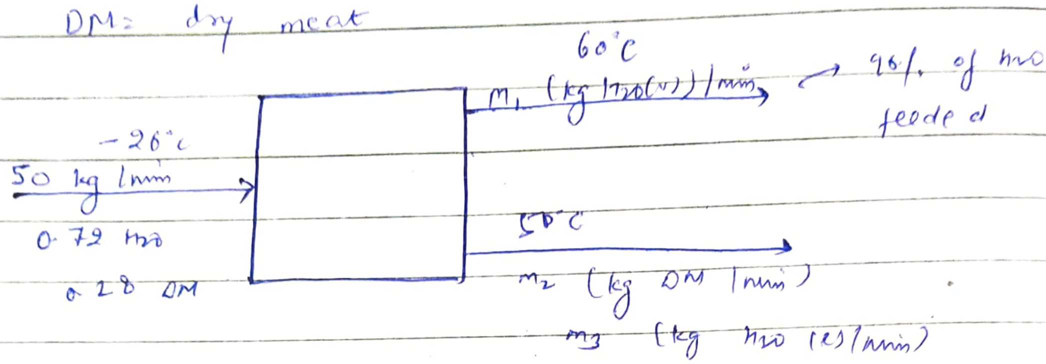
ASSIGNMENT-6

8.62 a) Basis: 50 kg (wet steak)/min

DM = dry meat



H_2O balance

$\dot{m}_1 = 0.96(0.72 \times 50) = 34.56$ kg H_2O(v)/min

$\dot{m}_3 = 0.04(0.72 \times 50) = 1.44$ kg H_2O(l)/min

Dry meat balance

$\dot{m}_2 = (0.28)(50) = 14$ kg DM/min

Reference states − DM @ −26°C, H_2O (l, 0°C)

substance	$\dot{m}_{in}$	$\hat{H}_{in}$	$\dot{m}_{out}$	$\hat{H}_{out}$
H_2O (v, 60°C)	—	—	34.56	2599
H_2O (l, 50°C)	—	—	1.44	209
H_2O (s, −26°C)	36	−390	—	—
dry meat	14	0	14	105

Dry meat − $\hat{H}(50°C) = C_p(50 - (-26)) = 1.38 \times 76 = 105$ kJ/kg

H_2O (s, −26°C): H_2O(l, 0°C) → H_2O (s, 0°C) → H_2O (s, −26°C)

$$\Delta\hat{H} = -\Delta\hat{H}_m(0°C) + \int_0^{-26} C_p\,dT = -\frac{6.01\text{ kJ}}{\text{mol}}\left|\frac{1\text{ mol}}{18\text{ g}}\right|\frac{10^3\text{ g}}{\text{kg}} + 2.17(-26) = \boxed{-390\text{ kJ/kg}}$$

$H_2O\,(l, 50°C) : H_2O\,(l, 0°C) \rightarrow H_2O\,(l, 50°C)$

$$\Delta\hat{H} = \int_0^{50} C_p\,dT = \frac{0.0754\ (\text{kJ})}{\text{mol}\ °C}\cdot\frac{50°C}{}\cdot\frac{1\ \text{mol}}{18.02\text{g}}\cdot\frac{10^3\text{g}}{\text{kg}} = 209\ \text{kJ/kg}$$

$H_2O\,(v, 60°C) = H_2O\,(l, 0°C) \rightarrow H_2O\,(l, 100°C) \rightarrow H_2O\,(v, 100°C) \downarrow H_2O\,(v, 60°C)$

$$\Delta\hat{H} = \frac{0.0754\ \text{kJ}}{\text{mol}\ °C}\cdot 100°C + 40.656\ \text{kJ/mol}$$

$$+ 40.656\ \text{kJ/mol} + \int_{100}^{60} C_p\,(H_2O_v)\,dT$$

$$= \frac{46.830}{\text{mol}}\cdot\frac{1\ \text{mol}}{18\text{g}}\cdot\frac{10^3\text{g}}{\text{kg}} = 2599\ \text{kJ/kg}$$

Energy balance

$$Q = \Delta H = \sum_{out} m_i\hat{h}_i - \sum_{in} m_i\hat{h}_i = \frac{1.06\times10^5\ \text{kJ}}{\text{min}}\cdot\frac{1\ \text{min}}{60\text{s}}\cdot\frac{1\ \text{kW}}{1\ \text{kJ/s}}$$

8.73

a) $\frac{400\ \text{kg}}{\text{min}}\cdot\frac{2.44\ \text{kg}\ H_2O}{97.56\ \text{kg air}} = 10$ kg H_2O evaporated / min

b) $h_a = \frac{10\ \text{kg}\ H_2O\,/\text{min}}{400\ \text{kg dry air}\,/\text{min}} = 0.025$ kg H_2O / kg dry air

$T_{db} = 50°C$

$\hat{H} = (116 - 1.1) = 115$ kJ / kg dry air, $T_{wb} = 33°C$

$h_r = 32\%$, $T_{\text{dew point}} = 28.5°C$

c) $T_{db} = 10°C$, saturated $\rightarrow h_a = 0.0077$ kg H_2O / kg dry air

$\hat{H} = 29.5$ kJ / kg dry air

d) $\frac{400 \text{ kg dry air}}{\text{min}} \left| \frac{(0.0250 - 0.0077) \text{ kg } H_2O}{\text{kg dry air}} \right. = 6.92 \text{ kg } H_2O/\text{min}$ condense

References: Dry air @ 0°C, H_2O (l) @ 0°C

Subst.	$\dot{m}_{in}$	$\hat{H}_{in}$	$\dot{m}_{out}$	$\hat{H}_{out}$
Air	400	115	400	29.5
H_2O (l)	–	–	6.92	92

H_2O (l, 0°C) $\rightarrow$ H_2O (l, 20°C)

$$\hat{H} = \frac{75.4 \text{ J}}{\text{mol °C}} \left| \frac{1 \text{ mol}}{18 \text{ g}} \right| (100)\text{°C} \left| \frac{1 \text{ kJ}}{10^3 \text{ J}} \right| \frac{10^3 \text{ g}}{1 \text{ kg}} = 92 \text{ kJ/kg}$$

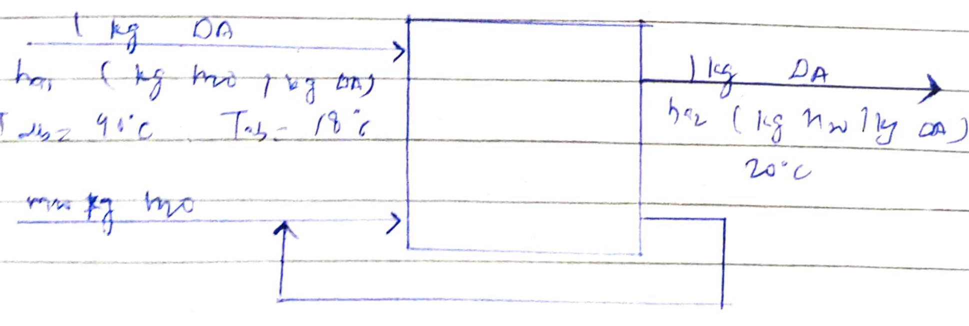
$$Q = \Delta H = \sum_{out} \dot{m}_i \hat{H}_i - \sum_{in} \dot{m}_i \hat{H}_i = \frac{-33927.8 \text{ kJ}}{\text{min}} \left| \frac{1 \text{ min}}{60 \text{ s}} \right| \frac{1 \text{ kW}}{1 \text{ kJ/s}}$$

$$= -565 \text{ kW}$$

e) T > 50°C, because the heat required to evaporate it is transfered from air which will cause it's temperature to drop. In order to calculate T_{in} of air we need to know the heat capacity & temperature changes of solids and the flow rate.

8.80 Basis: 1 kg DA

a)



Inlet air : $T_{db} = 40°C$

$T_{wb} = 18°C$ → $h_{a_1} = 0.0039$ kg H_2O / kg DA

Outlet air : $T_{db} = 20°C$

$T_{wb} = 18°C$ → $h_{a_2} = 0.0122$ kg H_2O / kg DA

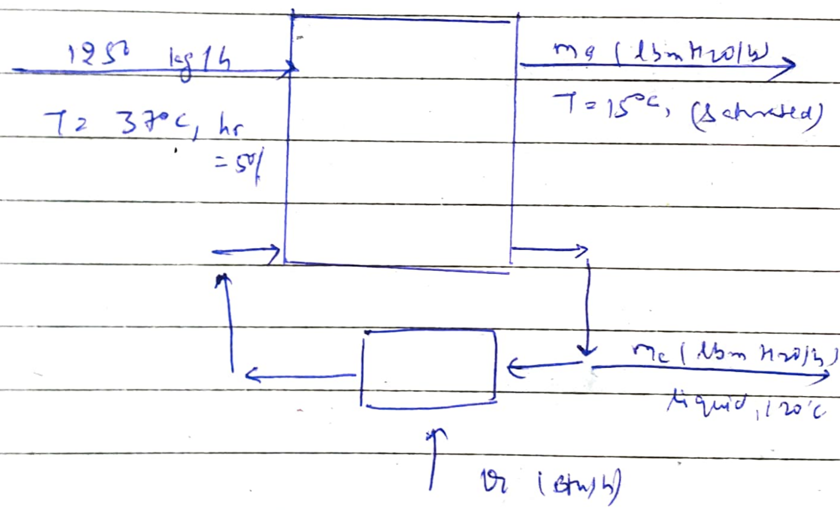
Overall H_2O balance :-

$m_w + (1)(h_{a_1}) = (1)(h_{a_2})$

$m_w = 0.0122 - 0.0039$

$= 0.0083$ kg H_2O / kg DA

b)



Inlet air :- $T_{db} =$

$h_r = 50\%$ } → $h_{a_1} = 0.0198$ kg H_2O / kg DA

$\hat{H}_1 = (88.5 - 0.5)$ kJ / kg DA

$= 88$ kJ / kg DA

Moles dry air : $m_a = \frac{1250 \text{ kg}}{h} \Big| \frac{1 \text{ kg DA}}{1.0198 \text{ kg}} = 1226$ kg DA/h

Outlet air :- $T_{db} = 15°C$, sat'd

$h_a = 0.0106$ kg H_2O / kg DA

$\hat{H}_2 = 42.1$ kJ / kg DA

Overall water balance :- $\dot{m_c} = \frac{1226 \text{ kg DA}}{h} \Big| \frac{(0.0198 - 0.0106) \text{ kg } H_2O}{\text{kg DA}}$

$\dot{m_c} = 11.3$ kg H_2O / h

Reference states for enthalpy calculations

$H_2O(l)$, dry air @ $0°C$, $C_p(H_2O, l) = 4.184\ kJ/kg\,°C$

$$H_2O(l, 12°C) \Rightarrow \hat{H} = \int_0^{12} C_p\,dT = 50.3\ kJ/kg$$

Overall system energy balance

$$\dot{Q}_c = \Delta\dot{H} = \sum_{out} \dot{m}_i \hat{H}_i - \sum_{in} \dot{m}_i \hat{H}_i$$

$$= \left[\frac{11.3\ kg\ H_2O}{h}\bigg|\frac{50.3\ kJ}{kg\ H_2O} + \frac{1226\ kg\ DA}{h}\bigg|\frac{(42.1-88)\ kJ}{kg\ DA}\right]$$

$$\left(\frac{1h}{3600\,s}\right)\left(\frac{1\,kW}{1\,kJ/s}\right)$$

$$\dot{Q}_c = -15.5\ kW$$

8.85 2 moles of $H_2SO_4 = 0.3\,(2 + n_{H_2O})$

$n_{H_2O} = 4.67$

$$r = \frac{4.67}{2} = 2.33\ \frac{mol\ H_2O}{mol\ H_2SO_4}$$

a) The system is a constant pressure system.

$$Q = \Delta H = n_{H_2SO_4}\,\Delta\hat{H}_s\,(25°C,\ r = 2.33) = \frac{2\ mol\ H_2SO_4}{}\bigg|\frac{-44.28\ kJ}{mol\ H_2SO_4}$$

$$Q = -88.6\ kJ$$

b) $m_{solution} = \dfrac{2\ mol\ H_2SO_4}{}\bigg|\dfrac{98.08\ g\ H_2SO_4}{mol} + \dfrac{4.67\ mol\ H_2O}{}\bigg|\dfrac{18\ g\ H_2O}{mol}$

$$= 280.2\ g$$

$$\Delta H = 0 \Rightarrow n_{H_2SO_4}\,\Delta\hat{H}_s\,(25°C,\ r = 2.33) + m\int_{25}^{T} C_p\,dT = 0$$

$$-88.6 + \frac{(280.6+150)\,g \;\big|\; 3.3\ J \;\big|\; (T-25)\,^\circ C \;\big|\; 1\ kJ}{\;\big|\; g\,^\circ C \;\big|\; \;\big|\; 10^3\ J} = 0$$

$T = 87^\circ C$

8.97 a) $x_{NH_3} = 0.3$, $y_{NH_3} = 0.96$ lbm NH_3 / lbm vapor

$T = 80^\circ F$

b) Basis : 1 lbm system mass

$\Rightarrow$ 0.9 lbm liq $\xrightarrow{x_{NH_3} = 0.3}$ 0.3 (0.9) = 0.27 lbm NH_3

0.7 (0.9) = 0.63 lbm H_2O

$\Rightarrow$ 0.1 lbm vapor $\xrightarrow{x_{NH_3} = 0.96}$ 0.96 (0.1) = 0.096 lbm NH_3

0.04 (0.1) = 0.004 lbm H_2O

mass fraction : $z_{NH_3} = \dfrac{(0.27 + 0.096)\ \text{lbm } NH_3}{1\ \text{lbm}}$

= 0.37 lbm NH_3 / lbm

$1 - 0.37 = 0.63$ lbm H_2O / lbm

Enthalpy :

$$\hat{H} = \frac{0.9\ \text{lbm liq.}}{\text{lbm}} \Bigg| \frac{-25\ \text{Btu}}{1\ \text{lbm liquid}}$$

$$+ \frac{0.1\ \text{lbm vapor}}{1\ \text{lbm}} \Bigg| \frac{670\ \text{Btu}}{1\ \text{lbm vapor}} = 44\ \text{Btu/lbm}$$