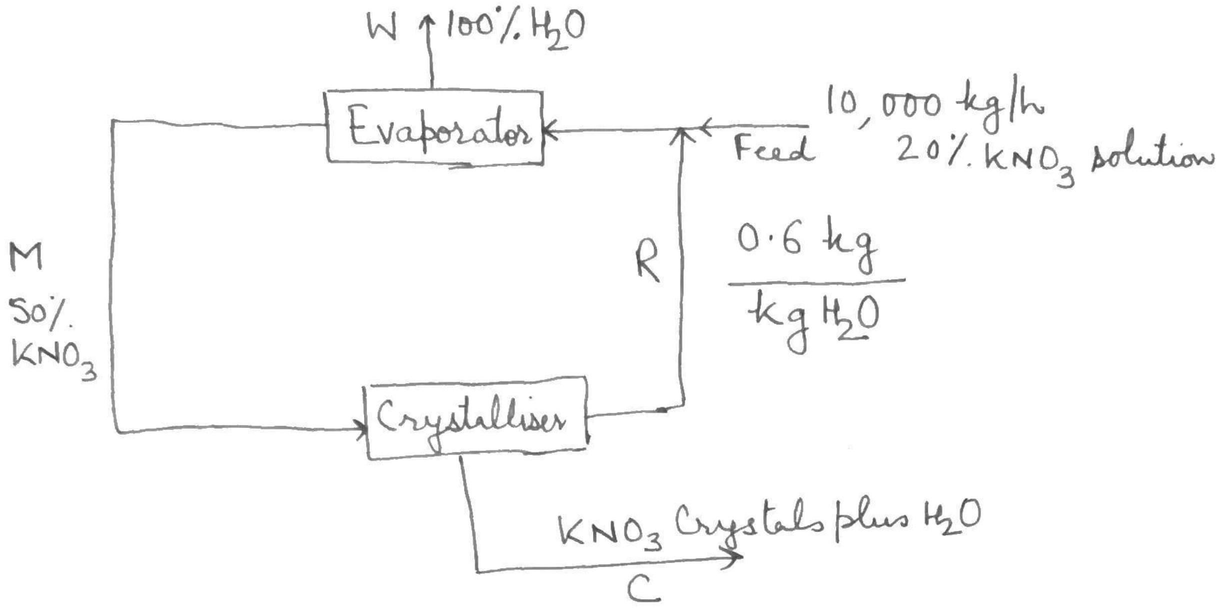
Solution Majors Exam

1.



Feed: 10,000 kg/h 20% KNO_3 Solution

Feed contains KNO_3 2000 kg

H_2O 8000 kg

Basis: 1 Hour

Overall Balance

KNO_3 Balance

In = Out

2000 kg 2000 kg (In stream C)

Stream C composition: KNO_3 96%

H_2O 4%

Stream C $\times$ 0.96 = 2000 kg

$$\text{Stream C} = \frac{2000 \text{ kg}}{0.96} = 2083.33 \text{ kg}$$

Stream C: KNO_3 = 2000 kg

H_2O = 83.33 kg

Balance on Crystalliser

KNO$_3$ Balance:

$$M \times 0.5 = 2000 + R\left(\frac{0.6}{1.6}\right)$$ {R is 0.6 kg per kg H$_2$O. i.e 0.6 kg KNO$_3$ in 1.6 kg}

H$_2$O Balance

$$M \times 0.5 = 83.33 + R\left(\frac{1}{1.6}\right)$$

$$\Rightarrow \quad 2000 + R\left(\frac{0.6}{1.6}\right) = 83.33 + R\left(\frac{1}{1.6}\right)$$

$$R\left[\frac{1}{1.6} - \frac{0.6}{1.6}\right] = 2000 - 83.33$$

$$\frac{R}{1.6} \cdot 0.4 = 1916.67$$

$$\boxed{R = 1916.67 \times 4 = 7666.68 \text{ kg/h}}$$

2. The value will remain same.

$$10 \frac{\text{cal}}{\text{gmol}\cdot\text{K}} \left| \frac{4.184\text{ J}}{1\text{ cal}} \right| \frac{1\text{ Btu}}{1055\text{ J}} \left| \frac{453.6\text{ gmol}}{1\text{ lbmol}} \right| \frac{1\,\Delta\text{K}}{1.8\,\Delta\text{R}}$$

$$\simeq 10 \frac{\text{Btu}}{\text{lbmol.R}} \simeq 10 \frac{\text{Btu}}{\text{lbmol.}^\circ\text{F}}$$

3. Closed System

Energy Balance Equation

$$\Delta U + \Delta E_k + \Delta E_p = Q - W.$$

$$\left.\begin{aligned} \Delta E_k &= 0 \\ \Delta E_p &= 0 \\ W &= 0 \end{aligned}\right\}$$

Energy Balance Eqnation simplifies

$$Q = \Delta U$$

$$\Delta U = (m C_p \Delta T)_{\text{cardboard}} + (m C_p \Delta T)_{\text{Potatoes}}$$

Mass of Cardboard $= 52 \times 24 \times 2.1 = 2620.8$ kg

Mass of Potatoes $= 52 \times 24 \times 20 = 24960$ kg

The temperature of cardboard and potatoes will be same.

~~cardboard~~

$$\Delta U = (2620.8\ \text{kg})(1.7\ \text{kJ/kg}\,^\circ\text{C})(0.3\,^\circ\text{C/h})$$

$$+ (24960\ \text{kg})(3.05\ \text{kJ/kg}\,^\circ\text{C})(0.3\,^\circ\text{C/h})$$

$$\Delta U = 1336.61\ \frac{\text{kJ}}{\text{h}} + 22838.4\ \frac{\text{kJ}}{\text{h}}$$

$$\Delta U = 24175.01\ \frac{\text{kJ}}{\text{h}} = 6.7153\ \frac{\text{kJ}}{\text{s}}$$

$$= \boxed{6.7\ \text{kW}}$$

4. $$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

Basis: 100 mole CO

$$\begin{array}{l} 100 \text{ mol } CO \\ x \text{ mol } O_2 \\ N_2 \ 3.76x \text{ mol.} \\ 100^\circ C \end{array} \longrightarrow \boxed{\text{Combustion}} \longrightarrow \begin{array}{ll} CO_2 & 100 \text{ mol.} \\ O_2 & (x-50) \text{ mol} \\ N_2 & 3.76x \text{ mol} \\ 1000^\circ C & \end{array}$$

References: $C(s)$, $O_2(g)$, $N_2(g)$ at $25^\circ C$, 1 atm.

Substance	n_{in} mol	$\hat{H}$ kJ/mol	n_{out} mol	$\hat{H}$ kJ/mol
CO	100	$\hat{H}_1$	—	—
O_2	x	$\hat{H}_2$	$x-50$	$\hat{H}_4$
N_2	$3.76x$	$\hat{H}_3$	$3.76x$	$\hat{H}_5$
CO_2	—	—	100	$\hat{H}_6$

$$\hat{H}_1: \quad \hat{H}_1 = (\Delta \hat{H}_f^\circ)_{CO} + \int_{25^\circ C}^{100^\circ C} (C_p)_{CO}\, dT$$

$$= -110.52 \text{ kJ/mol} + 2.19 \text{ kJ/mol} = -108.33 \text{ kJ/mol}$$

$$\hat{H}_2 = 2.24 \text{ kJ/mol}$$

$$\hat{H}_3 = 2.19 \text{ kJ/mol}$$

$$\hat{H}_4 = 32.47 \text{ kJ/mol}$$

$$\hat{H}_5 = 30.56 \text{ kJ/mol}$$

$$\hat{H}_6 = (\Delta \hat{H}_f^\circ)_{CO_2} + \int_{25^\circ C}^{1000^\circ C} (C_p)_{CO}\, dT = -393.5 \text{ kJ/mol} + 48.6 \text{ kJ/mol}$$

$$= -344.9 \text{ kJ/mol}$$

$$\Delta H = \sum_{\text{Exit}} n_i \hat{H}_i - \sum_{\text{Inlet}} n_i \hat{H}_i$$

$$= \left[(x-50)(32.47) + (3.76x)(30.56) + (100)(-344.9)\right] kJ$$

$$- \left[(100)(-108.33) + x(2.24) + (3.76x)(2.19)\right] kJ$$

$$= (3.76x)(30.56 - 2.19) + [32.47x - 1623.5 - 34490$$
$$+ 10833 - 2.24x]$$

$$\Delta H = 106.67x + 30.23x - 25280.5$$

$$\Delta H = 0$$

$$136.9x = 25280.5$$

$$x = 184.66 \text{ mol.}$$

O_2 supplied $= 184.66$ mol

O_2 needed for complete combustion $= 50$ mole

$$\% \text{ Excess Air} = \frac{O_2 \text{ enterinprocess} - O_2 \text{ required}}{O_2 \text{ required}} \times 100$$

$$= \frac{184.66 \text{ mol} - 50 \text{ mol}}{50 \text{ mol}} \times 100$$

$$= \frac{134.66 \text{ mol}}{50 \text{ mol}} \times 100$$

$$= 269.32 \%.$$