**Question 1: Non-reactive System**

100 kg of fresh cuttlefish that contains 80% water is fed to evaporator together with cuttlefish that is equivalent to 10 sodium carbonate. The alkaline solution of sodium carbonate is used to soften the dried cuttlefish. However, the alkaline solution cannot be reacted under high temperature. The water is evaporated in the evaporation unit with an efficiency of 75%. The output from the evaporator are all mixed with the bypassed cuttlefish to get the desired final amount of dried cuttlefish, sodium carbonate and water and it is given that the composition of sodium carbonate is 10 times of the cuttlefish with 45% of water from the evaporator.

i) Construct a flow chart and perform all the degree of freedoms. (8 marks)

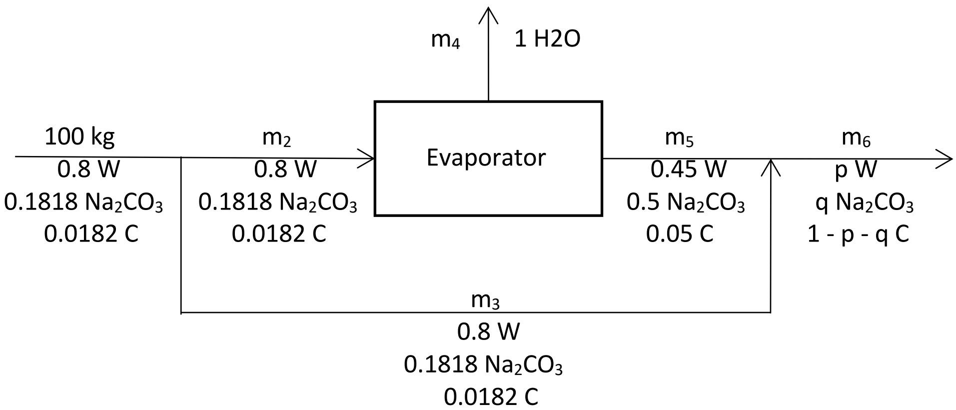
ii) Find the mass flowrates and the compositions involved in the process. (11 marks)

iii) Work out the mass flowrates of fresh cuttlefish (feed) in pounds to be getting 4 pounds of dried cuttlefish for 7 hours of working operation. (3 marks)

iv) An average of 15 hours produces 1000 pounds of dried cuttlefish. If 1 pound of cuttlefish is sold in the market for RM11.30, find the annual revenue of the cuttlefish sold. (3 marks)

Answers for Question 1:

i)




DOF overall = 4 ($m_4$ , $m_6$ , p , q) - 3 (W, $Na_2CO_3$, C) - 1 (efficiency 95%) = 0
DOF split = 2 ($m_2$ , $m_3$) - 3 (W, $Na_2CO_3$, C) - 0 = -1
DOF evaporator = 3 ($m_2$ , $m_4$ , $m_5$) - 3 ( W, $Na_2CO_3$, C) - 2 (ratio between $Na_2CO_3$ and C) = -1
DOF combine = 5 ($m_3$ , $m_5$ , $m_6$ , p , q) - 3 (W, $Na_2CO_3$, C) - 1 (ratio between $Na_2CO_3$ and C) = 1

ii) Efficiency = 75%

$(m_4)(1) = (0.75)(100)(0.8)$

$m_4 = 60$ kg

Overall:

Overall: $100 = m_4 + m_6$

$m_6 = 40$ kg

W: $80 = m_4 + (m_6)(p)$

$p = \dfrac{80 - 60}{40} = 0.5$

N: $18.18 = (m_6)(q)$

$q = \dfrac{18.18}{40} = 0.455$

C: $1 - p - q = 1 - 0.5 - 0.455 = 0.045$

Combine:

Overall: $m_3 + m_5 = m_6$

$m_3 + m_5 = 40$ kg , $m_3 = 40 - m_5$

N: $0.1818m_3 + 0.5m_5 = 18.2$

C: $0.0182m_3 + 0.05m_5 = 1.8$

W: $(0.8)(m_3) + (0.45)(m_5) = 20$

$(0.8)(40 - m_5) + (0.45)(m_5) = 20$

$m_5 = 34.29$ kg

$m_3 = 40 - 34.29 = 5.71$ kg

Evaporator:

Overall: $m_2 = m_4 + m_5$

$m_2 = 60 + 32.29 = 92.29$ kg

iii) $100\ \cancel{kg} \times \dfrac{2.2046 \text{ pounds}}{1\ \cancel{kg}} = 220.46$ pounds (feed)

$40\ \cancel{kg} \times \dfrac{2.2046 \text{ pounds}}{1\ \cancel{kg}} = 88.184$ pounds ($m_6$)

220.46 : 88.184

y : 4 y = 10 pounds

$\dot{M}$ of feed : $\dfrac{10 \text{ pounds}}{7 \text{ hours}} = 1.43$ pounds/hr

iv) $\dfrac{1000 \text{ pounds}}{15 \text{ hours}} \times \dfrac{24 \text{ hours}}{1 \text{ day}} \times \text{RM } 11.30 \times 88.184 \text{ pounds} \times \dfrac{365 \text{ days}}{1 \text{ year}}$

= RM582 millions

## Question 2: Reactive System

In the production of ammonia, Haber Process is used in industry. Nitrogen is collected from air and hydrogen from crude oil are purified to remove duct particles like $CO_2$ and $H_2O$ from the mixture. The gas mixture is the compressed in a compressor at 500 atm before it flows to heat exchanger unit to remove heat. 30 mol/hr of nitrogen enters the condenser with hydrogen to produce the preferred amount of 50 mol/hr of $NH_3$. Given the unreacted gas of nitrogen is one-third of hydrogen gas.

i) Construct a balanced chemical equation. (2 marks)

ii) Draw a flowchart of the condenser and perform degree of freedom. (5 marks)

iii) Calculate the mass flow rates of $n_iH_2$, $n_fH_2$ and $n_fN_2$ given the atomic weight of nitrogen and hydrogen are 14 and 1 respectively by using atomic species method. (9 marks)

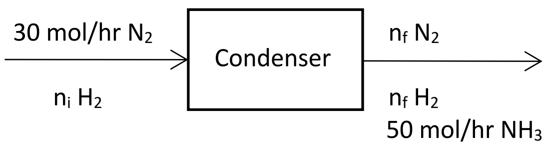
iv) The condenser feed contains 27g of $N_2$ and 6.8g of $H_2$. Determine the limiting and excess reactants and their fractional conversions. (6 marks)

v) What should be done to the unreacted gases, $N_2$ and $H_2$? Explain. (2 marks)

Answers for Question 2:

i) $N_2 + 3H_2 \rightarrow 2NH_3$

ii)




DOF = 3 ($n_i$ $H_2$, $n_f$ $N_2$, $n_f$ $H_2$) + 1 ($N_2 + 3H_2 \rightarrow 2NH_3$) - 3 ($N_2$, $H_2$, $NH_3$) - 1 (ratio $N_2$ and $H_2$)
= 0

iii) N balance:

$(30)(2) = (n_f\ N_2)(2) + (50)(1)$
$n_f\ N_2 = 5$ mol/hr
MW $N_2$ = 28 g/mol

$$\dot{m}\ n_f\ N_2 = \frac{5\ \cancel{mol}}{hr} \times \frac{28\ g}{\cancel{mol}} = 140\ g/hr$$

$N_2$ : $H_2$
1 : 3
$n_f\ H_2 = 3n_f\ N_2 = (3)(5) = 15$ mol/hr
MW H2 = 2g/mol

$$\dot{m}\ n_f\ H_2 = \frac{15\ \cancel{mol}}{hr} \times \frac{2\ g}{\cancel{mol}} = 30\ g/hr$$

H balance:

$(n_i\ H_2)(2) = (15)(2) + (50)(3)$
$n_i\ H_2 = 90$ mol/hr
MW $H_2 = 2$ g/mol
$\dot{m}\ n_i\ H_2 = \frac{90\ \cancel{mol}}{hr} \times \frac{2\ g}{\cancel{mol}} = 180$ g/hr

iv) $n\ H_2 = \frac{6.8\ g}{2\ g/mol} = 3.4$ mol provided (excess reactant as only 3 mol needed)

$n\ N_2 = \frac{27\ g}{28\ g/mol} = 0.96$ mol provided (limiting reactant as 1 mol needed)

$f\ H_2 = \frac{3.4 - 3}{3} = 0.133$

$f\ N_2 = \frac{1 - 0.96}{0.96} = 0.042$

v) The reacted gases of $N_2$ and $H_2$ should be recycled to produce the highest yield of ammonia, $NH_3$.

**PRINCIPLE OF CHEMICAL ENGINEERING**
**CEB 1043**

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PCE ASSIGNMENT: NON-REACTIVE AND REACTIVE SYSTEMS

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