MS Excel and VBA for Chemical Engineers

TSEC - Online Certificate Course

QUESTION SET

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1 Material Balance without Chemical reactions

1.1 Mixing

The waste acid from a nitrating process contains 21% HNO_3, 55% H_2SO_4 and 24% H_2O by weight. This acid is to be concentrated to contain 28% HNO_3 and 62% H_2SO_4 by addition of concentrated sulphuric acid containing 93% H_2SO_4 and concentrated Nitric Acid containing 90% HNO_3.

Calculate the weights of waste, and concentrated sulphuric acid and nitric acid that must be combined to obtain 1000 kg of the desired.

1.2 Bypass

1.2.1 Direct method

In a textile industry, it is desired to make 24% solution (by weight) of caustic soda for a mercerisation process. Due to very high heat of dissolution of caustic soda in water, the above solution is prepared by two step process.

First, in a dissolution tank, caustic soda is dissolved in the correct quantity of water to produce 50% (by weight) solution. After complete dissolution and cooling, the solution is taken to dilution tank where some more water is added to produce 24% solution. Assuming no evaporation loss of water in dissolution tank. Calculate the weight ratio of water fed to dissolution tank to bypassed water to dilution tank

1.2.2 Solver based method

Fresh juice contains 15% solids and 85% water by weight and is to be concentrated to contain 40% solids by weight.

In a single evaporation system, it is found that volatile constituents of juice escape with water leaving the concentrated juice with a flat taste. To overcome this problem, part of the fresh juice bypasses the evaporator. Operation is shown schematically in the figure.

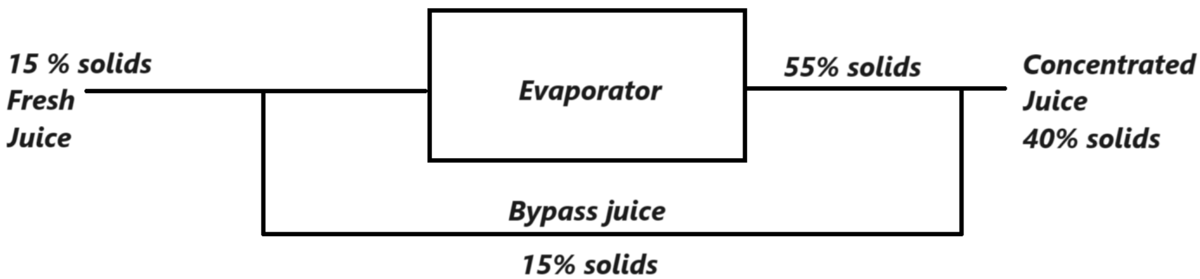

Figure 1: Bypass evaporation system

Calculate:

1. The fraction of juice that bypasses the evaporator
2. The concentrated juice produced (containing 40% solids) per 100 kg of fresh juice to the process

2 Material Balance with Chemical reactions

2.1 Direct method

In the production of Sulphur dioxide 100 $kmols$ of SO_2 and 100 $kmols$ of O_2 are fed to the reactor. If the percent conversion of SO_2 is 80 calculate the composition of product stream. The reactions involved are

$$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3 \tag{1}$$

2.2 Goal seek based method

The analysis of the gas entering the secondary converter in a sulphuric acid plant is 4% SO_2, 13% O_2 and 83% N_2 (on volume basis). The gas leaving the converter contains 0.45% SO_2 on SO_3 free basis (by volume).

Calculate

1. The percentage of SO_2 entering the converter getting converted to SO_3.

2. The actual analysis of gases leaving the converter on volume basis

3 Material balance with recycle

3.1 System of interconnected tanks (without reaction)

Let us imagine three perfectly stirred tanks, interconnected as per Figure 2

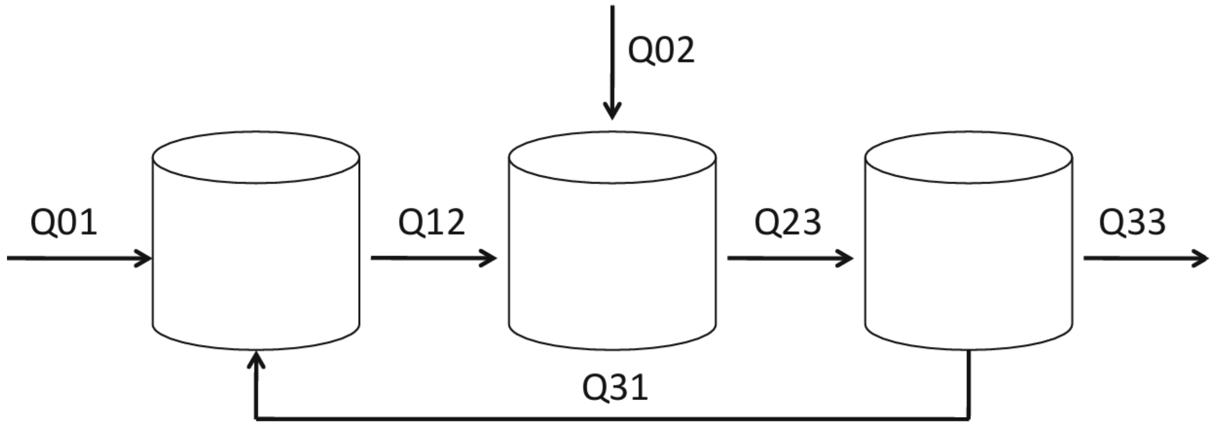

Figure 2: Three interconnected tanks

At the beginning, there is the same volume of pure water in all tanks, and pure water is fed into tanks 1 and 2 at rates Q_{01} and Q_{02} (m^3/min), respectively. This system has a recycle, and part of the effluent of tank 3 returns to tank 1, at a rate Q_{31} (m^3/min). During the entire process, the volume of liquid in the three tanks remains constant. The amounts of liquid that leave tanks 1 and 2 to enter tanks 2 and 3, respectively, are Q_{12} and Q_{23} (m^3/min), and the amount of water that leaves tank 3 is Q_{33} (m^3/min). Table 1 shows numerical values for all flow rates.

At a certain point, the streams Q_{01} and Q_{02} start feeding tanks 1 and 2 with a NaOH

Q_{01}	Q_{02}	Q_{31}	$Q_{12} = Q_{01} + Q_{31}$	$Q_{23}Q_{02} + Q_{12}$	$Q_{33} = Q_{23} - Q_{31}$	Units
5	1	2	7	8	6	m^3/min

Table 1: Volumetric flow rates for the three interconnected tanks

Tank	Unit (mol/min)
1	$Q_{01}C_{01} - Q_{12}C_1 + Q_{31}C_3 = 0$
2	$Q_{12}C_1 - Q_{23}C_2 + Q_{02}C_{02} = 0$
3	$Q_{23}C_2 - Q_{33}C_3 - Q_{31}C_3 = 0$

Table 2: Mass balance for the three tanks

solution with concentrations of 10 mol/m^3 (C_{01}) and 1 mol/m^3 (C_{02}), respectively, instead of pure water, although all flow rates remain the same. What are the NaOH concentrations in all of the tanks when a steady state is reached?

3.2 Simple flowsheet (with reaction)

The process of manufacturing methanol is shown in the figure below

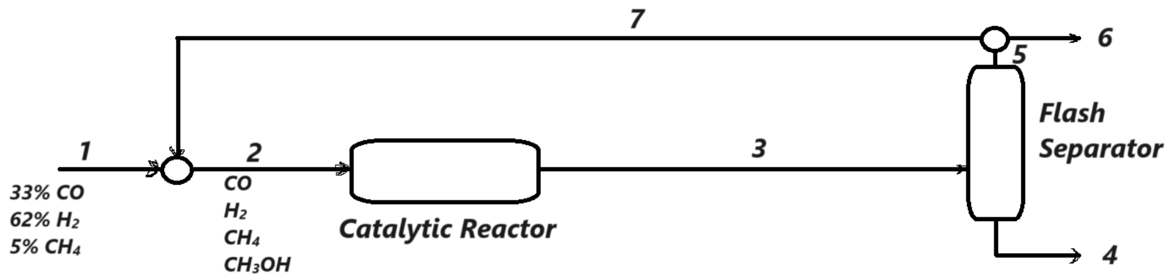

Figure 3: Methanol production process

The reactions at different parts of the process are given below

$$CO|_4 = 0.03 \times CO|_3 \tag{2}$$
$$H_2|_4 = 0.02 \times H_2|_3 \tag{3}$$
$$CH_3OH|_4 = 0.96 \times CH_3OH|_3 \tag{4}$$
$$CH_4|_4 = 0.04 \times CH_4|_3 \tag{5}$$

The conversion of CO is 60% and the purge stream is 10% of stream 5. Assume 1000 kmol/hr of feed and solve the flowsheet.