MS Excel and VBA: Module 2

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1 System of Linear Equations Example

1.1 Linear Material Balances in Process Flowsheet

Adapted from: Biegler, L. T., Grossmann, I. E., Westerberg, A. W. (1997) *Systematic Methods of Chemical Process Design*. Prentice Hall. 796p.

The flowsheet in block-diagram form for the production of ethanol is given below.

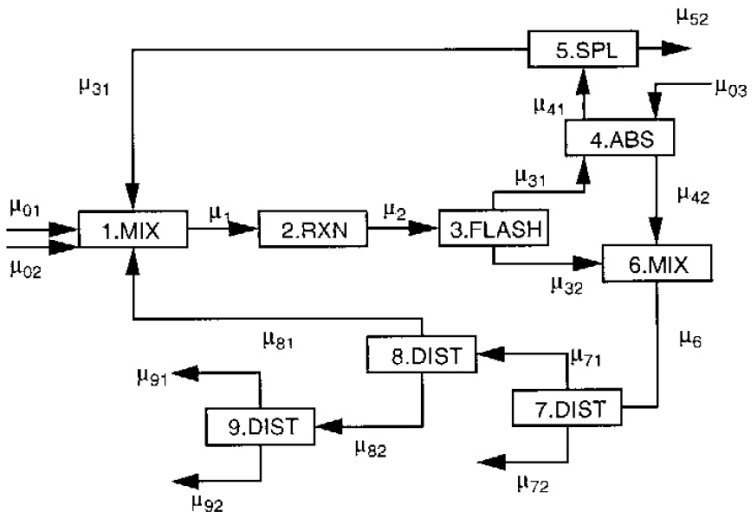

Figure 1: Flowsheet for the production of ethanol. μ_{ij} represents molar flows from unit i and j-th output stream (if more than one).

We want to perform a mass balance on ethylene and then calculate all its flowrates. After obtaining the *split fractions* of each unit, we derive the

following linear equations (for ethylene):

$$\begin{aligned}
\mu_1 &= \mu_{81} + \mu_{01} + \mu_{51} \\
\mu_2 &= 0.93\mu_1 \\
\mu_{31} &= 0.985\mu_2 \\
\mu_{32} &= 0.015\mu_2 \\
\mu_{41} &= 0.979\mu_{31} \\
\mu_{42} &= 0.021\mu_{31} \\
\mu_{51} &= 0.995\mu_{41} \\
\mu_{52} &= 0.005\mu_{41} \\
\mu_6 &= \mu_{32} + \mu_{42} \\
\mu_{71} &= \mu_6 \\
\mu_{81} &= \mu_{71}
\end{aligned}$$

where $\mu_{01} = 96\,\mathrm{gmol\,s^{-1}}$.

1.2 Solution

Notice that we have 11 (linearly independent) equations and 11 variables. In order to solve this system with Excel Solver, we first write it as a Linear Optimization problem (see file `Solver_Examples.xlsx`, worksheet "LE Example").

Using the Solver add-in in MS Excel, the solution is (flowrates of ethylene):

$$\begin{aligned}
\mu_1 &= 1288.87\,\mathrm{gmol\,s^{-1}} \\
\mu_2 &= 1198.65\,\mathrm{gmol\,s^{-1}} \\
\mu_{31} &= 1180.67\,\mathrm{gmol\,s^{-1}} \\
\mu_{32} &= 17.98\,\mathrm{gmol\,s^{-1}} \\
\mu_{41} &= 1155.87\,\mathrm{gmol\,s^{-1}} \\
\mu_{42} &= 24.79\,\mathrm{gmol\,s^{-1}} \\
\mu_{51} &= 1150.09\,\mathrm{gmol\,s^{-1}} \\
\mu_{52} &= 5.78\,\mathrm{gmol\,s^{-1}} \\
\mu_6 &= 42.77\,\mathrm{gmol\,s^{-1}} \\
\mu_{71} &= 42.77\,\mathrm{gmol\,s^{-1}} \\
\mu_{81} &= 42.77\,\mathrm{gmol\,s^{-1}}
\end{aligned}$$