Practical Session #1

Exercise 1

A biological process is operated in a batch reactor characterized by the growth of biomass (B) at a loss of substrate (S). The material balances for the two species are:

$$\begin{cases} \dfrac{dB}{dt} = \dfrac{k_1 BS}{k_2 + S} \\ \dfrac{dS}{dt} = -k_3 \dfrac{k_1 BS}{k_2 + S} \end{cases}$$

Determine the dynamics of both the substrate and biomass over 15 h, knowing that:

$k_1 = 0.5 \text{ h}^{-1}$

$k_2 = 10^{-7} \text{ kmol/m}^3$

$k_3 = 0.6$

The initial conditions are:

$$\begin{cases} B(0) = 0.03 \text{ kmol/m}^3 \\ S(0) = 4.5 \text{ kmol/m}^3 \end{cases}$$

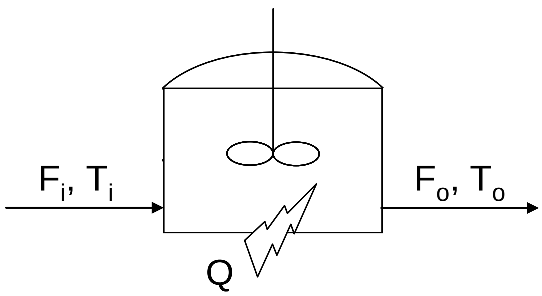
Solve the problem in Matlab. Modify the parameters for the error control of the ordinary differential system by adopting a relative tolerance of 10^{-8} and an absolute one of 10^{-12} (respect to the default Matlab values). Compare the two dynamics.

Exercise 2

Consider an intermediate storage tank that is perfectly mixed (CST) and heated. Assuming a steady state regime for the liquid level in the tank, evaluate the dynamics of the outlet temperature after a step disturbance of 30 °C on the inlet temperature occurring at t=150 s.

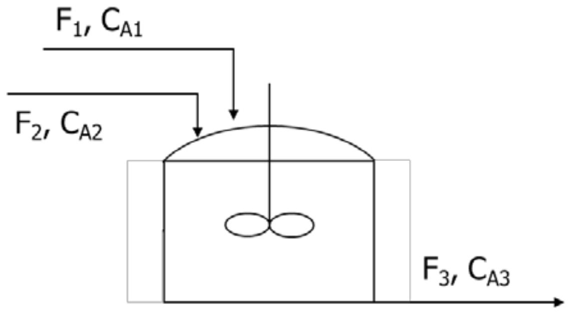
Data:

- Heat power supplied to the system: $Q = 1 \text{MW}$
- Inlet flowrate: $F_i = 8 \text{kmol/s}$
- Mass holdup of the CST: $m = 100 \text{kmol}$
- Specific heat of the mixture: $cp = 2.5 \text{ kJ/kmol K}$
- Inlet temperature: $T_i = 300 \text{K}$



Exercise 3

Let us consider the mixing of two streams featuring different concentrations of the same component. Consider isothermal perfectly mixed conditions.



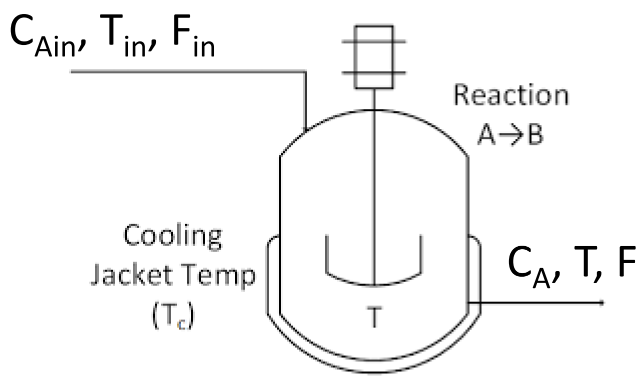
Input data:

- Stream 1: $F_1 = 2\,\mathrm{m^3/h}$; $c_1 = 0.5\,\mathrm{kmol/m^3}$
- Stream 2: $F_2 = 10\,\mathrm{m^3/h}$; $c_2 = 6\,\mathrm{kmol/m^3}$

Determine the outlet concentration dynamics from the mixer when the flowrate, F_1, varies linearly with the time as follows: $F_1 = 0.04 \times \mathrm{t}$, up to the maximum value of: $20\,\mathrm{m^3/h}$.

Exercise 4

A liquid stream of A undergoes an isomerization process (A→B) in a jacketed CSTR reactor (V=0.785 m^3).



The reaction is exothermic (ΔH_r=-50000 *J/mol*) and the cooling fluid is water at ambient temperature (T_c=300 *K*). The product of the global heat exchange coefficient (U) and the heat exchange area (A) is 150 *J/min/K*.

The liquid stream of A fed to the reactor is 0.005 *m^3/min* and its temperature is T_{in}=300 *K*. The inlet concentration of A (C_{Ain}) is 0.03 *mol/m^3*. The reaction can be described by a first order equation whose rate constant can be expressed as *k=k0*exp(-Ea/RT)*, where k_0=6.0E+02 *1/min* and Ea=3x10^4 *J/mol*. Density and specific heat of the inlet and outlet flow can be assumed constant and equal to 1200 *Kg/m^3* and 25 *J/mol/K*, respectively.

Assuming a steady state regime for the volume V of liquid inside the reactor, determine the dynamics of temperature, concentration of reactant A and of product B.