University of Pretoria

Department of Chemical Engineering

Reactor Design 410 – CRO 410 Normal Exam – Part 1

07 July 2020 Full Marks = 25 Time = 120 minutes

Scenario description:

The elementary reversible liquid phase isomerisation reaction is studied. Pure A, at the inlet conditions as specified in the table below, must be processed in a steady state flow reactor:

$$A \leftrightharpoons B$$

Some kinetic and thermodynamic data on the reaction are also given in the table below:

Volumetric flow rate (q) *you may assume it does not change as A gets converted to B*	1.0×10^{-3}	$m^3.s^{-1}$
Inlet molar flow rate of A (F_{A_o})	0.1	$mol.s^{-1}$
Inlet Temperature (T_o)	400	K
Forward reaction rate constant ((k_i) **at $\boldsymbol{T = 400\ K}$**	1.67×10^{-3}	s^{-1}
Activation Energy (E)	80000	$J.mol^{-1}$
Heat capacity of A (C_{p_A})`	120	$J.mol^{-1}.K^{-1}$
Heat capacity of B (C_{p_B})`	120	$J.mol^{-1}.K^{-1}$
Heat of reaction @ $T = 298\ K$ $\Delta H_{rx_{298}}$	-100000	$J.mol^{-1}$
Equilibrium constant K_c @ $\boldsymbol{T = 400\ K}$	100	–

Questions on Scenario

1. ***NBNBNB*** *Declare that this is your own work. Please read the declaration provided in the test canvas and confirm whether it is TRUE/FALSE*

2. What is the maximum possible conversion that can be achieved in any type of *adiabatic* reactor given the inlet conditions of this system? Give answer as a percentage and round to three significant numbers (e.g. 12.3) [5]

3. A CSTR with a volume of $V_{CSTR} = 0.01\ m^3$ is available. What is the maximum possible conversion of A that can be achieved in this CSTR? (operating temperature can be selected – so not restricted to adiabatic operation). Give answer as a percentage and round to three significant numbers (e.g. 12.3) [5]

4. Would it be possible to achieve this conversion (calculated in 3), if the CSTR is operated adiabatically and you have the option of increaseing or decreasing the reactor inlet temperature? Comment on the practicality of this approach. Submit your answer (YES/NO) as WELL as your explanation and comments in the essay block provided. You may support your answer by illustrations or images in your pdf document uploaded in 6 and/or 7 – refer to them in the text box [4]

5. The CSTR is now supplied with a heating/cooling jacket such that $UA = 240\ W.K^{-1}$. Specify the utility temperature (T_u) that must be used in order to achieve the maximum possible conversion you calculated in the reactor if the ***inlet*** temperature is kept at $T_o = 400\ K$. Give answer in K and round to a whole number (i.e. 321) [4]

6. Assume that **32% conversion of A** is achieved in the CSTR reactor (not the correct answer but use this value for calculations in Question 6 and Question 7) The outlet from the CSTR is now cooled to a temperature of 350 K in a heat exchanger where no reaction takes place. This cooled stream is fed to an ***adiabatic*** PFR. Specify the volume of that PFR if the OVERALL conversion of A that must be achieved in this two-reactor system must be 45%. Give answer in units of m^3 and round to 3 significant numbers (i.e. 0.123 or 1.23) [5]

7. What is the outlet temperature from this PFR reactor? Give answer in K and round to a whole number (e.g. 432) [2]

8. Upload a pdf file with your work that will be considered for method marks

9. Upload a **pdf version** of your notebook file if you feel that it is well annotated, with all equations used given in markdown cells or clearly annotated (not compulsory)

NB: Start your filenames with your surname followed by your initials followed by your student numer