University of Pretoria

Department of Chemical Engineering

Reactor Design 410 – CRO 410 Normal Exam – Part 2

14 July 2020 Full Marks = 22 Time = 120 minutes

Scenario description:

The catalysed 2nd order irreversible liquid phase where $2A \longrightarrow B$, is studied in a CSTR reactor with a volume of $\boldsymbol{V = 8\ m^3}$. The concentration of the porous catalyst particles in the reactor is kept constant at $\boldsymbol{C_{cat} = 19.4\ kg.m^{-3}}$ for all the different runs. The reactor is operated adiabatically. Other variables than may be assumed constant between the different runs are summarised in the table below:

Volumetric flow rate (Q) *you may assume it does not change as A gets converted to B*	0.03	$m^3.s^{-1}$
Inlet concentration of A (C_{A_o})	25	$kmol.m^{-3}$
Inlet concentration of B (C_{B_o})	0	$kmol.m^{-3}$
Inlet Temperature (T_o)	350	K
Heat capacity of A (C_{p_A}) - ($\Delta C_{p_{RX}} \approx 0$)	140	$J.mol^{-1}.K^{-1}$
Catalyst density (ρ_c)	2300	$kg.m^{-3}$
Effective diffusivity of A in catalyst pores (D_e)	4.5×10^{-9}	$m^2.s^{-1}$

Results on the steady state operating temperature (T) of the reactor as well as the conversion of A (x_A) are reported for different catalyst particle sizes and different stirrer speeds in the reactor:

Particle diameter (d_p) mm	**Stirrer Speed rpm**	**Conversion of A** %	**Reactor Temperature (T) (K)**
1.0	800	70.0	420.0
1.5	800	56.8	406.8
2.0	1200	43.8	393.8
2.0	800	43.8	393.8

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. Based on the results, can you conclude that all the runs are free of any external mass transfer effects? Explain your answer. Give your answer (Yes/No) followed by your explanation in the text box provided [3]

Regardless of your answer in number 2, you may now assume that all the runs are free of external diffusion effects for Questions 3 and 4.

3. What is the heat of reaction (ΔH_{RX}) in units of $J.mol_{RX}^{-1}$? Round to a whole number, accuracy $\pm 100\ J.mol^{-1}$ [4]

4. What is the true activation energy of this reaction (E) in units of $J.mol^{-1}$? Round to a whole number (accuracy $\pm 500\ J.mol^{-1}$) [8]

NBNB – Ignore your answers in 3 and 4 and use an activation energy of $\boldsymbol{E = 78000\ J.mol^{-1}}$ and a heat of reaction of $\boldsymbol{\Delta H = -35000\ J.mol_{RX}^{-1}}$ for Question 5 *(Note that these are not necessarily the correct answers – but will be used in the memo for Question 5)*

5. The stirrer speed in the reactor with $d_p = 1.5\ mm$ catalyst particles is now halved to 400 rpm and a conversion of $x_A = 40\ \%$ is measured when steady state is reached. If you may still assume that the run at 800 rpm is free of any mass transfer effects, determine the external mass transfer coefficient, $k_c\ (m.s^{-1})$ for this particle diameter at $400\ rpm$.. (Round to three significant numbers e.g. 0.00123 or 0.000123) [7]

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Start ALL file names with your Surname and Initials, followed by your student number and any distinguising details about the information in that file.

(e.g. DuToit_EL_123456_written.pdf OR *DuToit_EL123456_notebook.pdf*).