CRO410 Semester Test 1 2019

Full marks = 30

Question 1 [18]

The irreversible liquid phase hydration reaction:

$$A + B \rightarrow C$$

takes place in two CSTR reactors with the same volume ($V_1 = V_2 = 2000\ \ell$) operated in series. The volumetric flow rate to the first reactor is $Q_o = 3\ \ell.s^{-1}$. It contains an equimolar mixture of A and B such that $C_{A_0} = C_{B_0} = 5\ mol.\ell^{-1}$. The feed stream also contains in **inert** component, I, at a concentration of $C_{I0} = 5\ mol.\ell^{-1}$. The inlet temperature to this first reactor is $T_o = 350\ K$. The first reactor has a heating coil with $UA = 3000\frac{W}{K}$ through which a utility stream with a constant temperature, T_u, flows. The second reactor is operated adiabatically. An elementary rate expression may be assumed for the reaction rate of component A, i.e. $r_A = -kC_AC_B$. Additional data on the reaction is given in the table below:

Parameter	Value	Units
k_o	1500	$\ell.mol^{-1}.s^{-1}$
E	65 000	$J.mol^{-1}$
ΔH^o_{RX}	−60 000	$J.mol^{-1}_{RX}$
Cp_A	100	$J.mol^{-1}.K^{-1}$
Cp_B	70	$J.mol^{-1}.K^{-1}$
Cp_C	170	$J.mol^{-1}.K^{-1}$
Cp_{inert}	60	$J.mol^{-1}.K^{-1}$

The products from the first reactor are separated by appropriate processing and only the unconverted reactants and the inert component is fed to the second reactor. I.e. the separated stream contains only pure C. You may assume the separation process to be isothermal (see figure 1 on the figures page). The *overall* conversion of reactant A in this system is **93 %.**

a) Determine the temperature of the utility (T_u).that is used for heat transfer in Reactor 1 [16]

b) What is the volumetric flowrate out of the second reactor Q_2 under these conditions? (show calculations AND answer) [2]

NB!! You may assume ideal mixing and equal densities ($kg.m^{-3}$) of all the components in the system. The addition of a utility in reactor 1 ensures that no multiplicity issues are experienced in any of the two reactors.

Question 2 *[12]*

The gas phase reaction given below is allowed to take place in an ***adiabatically*** operated PBR packed with ***40 kg*** of catalyst.

$$A \longrightarrow B + C$$

Some information on the reaction and the reactor is given in the table below:

Parameter	Value	Units
F_{A_0}	0.11	$kmol.s^{-1}$
P_o	200	kPa
T_o	150	$°C$
ΔH_{RX}	-19000	$J.mol^{-1}$
K_{Ergun}	0.4	$kPa.kg^{-1}$

a) What will K_{Ergun} be if the reactor diameter is *halved*? (same units as in the table) [2]

Figure 2 (see figures page) shows the conversion of A for the gas phase reactor described in the table as a function of the catalyst mass:

b) Redraw this figure in your answer book. On the same axes set, show the conversion profile that you would expect if the reactor was operated **isothermally** i.s.o. adiabatically. NO MODELLING required, only a qualitative comparison, cleary showing the difference in shape of the profile and expected conversion (higher or lower) at the outlet. Explain the differences or similarities in the conversion profiles. [3]

c) State whether you think the amount of catalyst (kg) that would be required in a CSTR to achieve the same conversion shown in the figure will be less, more, or the same as that in the PBR (40 kg). Explain your answer [4]

d) Once again redraw figure 2 in your answer book and on the same axes set, show the conversion profile that you would expect if ΔH_{RX} is double that given in the table above (still exothermic). Explain the shape of your graph. [3]

Use equations, graphs, refer to relevant parameters that is impacted by different variables in order to explain your answers in b) to d) – try not to write essays.

Question 1:

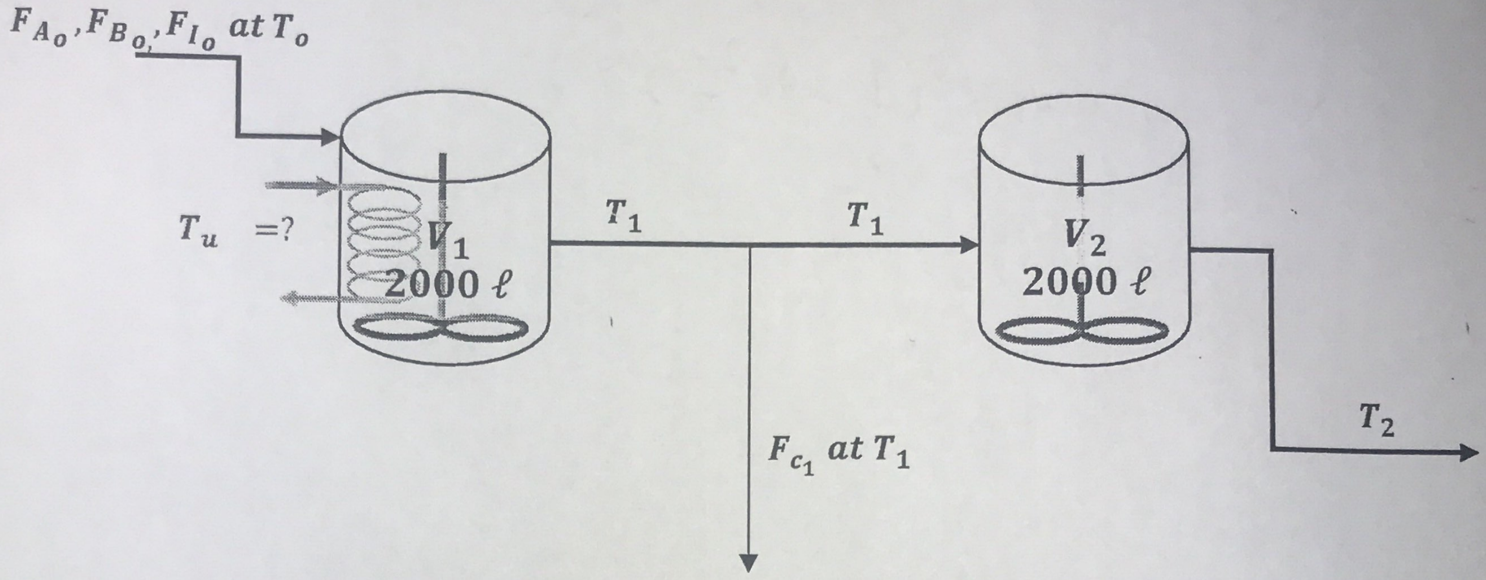

Figure 1: Reactors in series for Question 1

Question 2

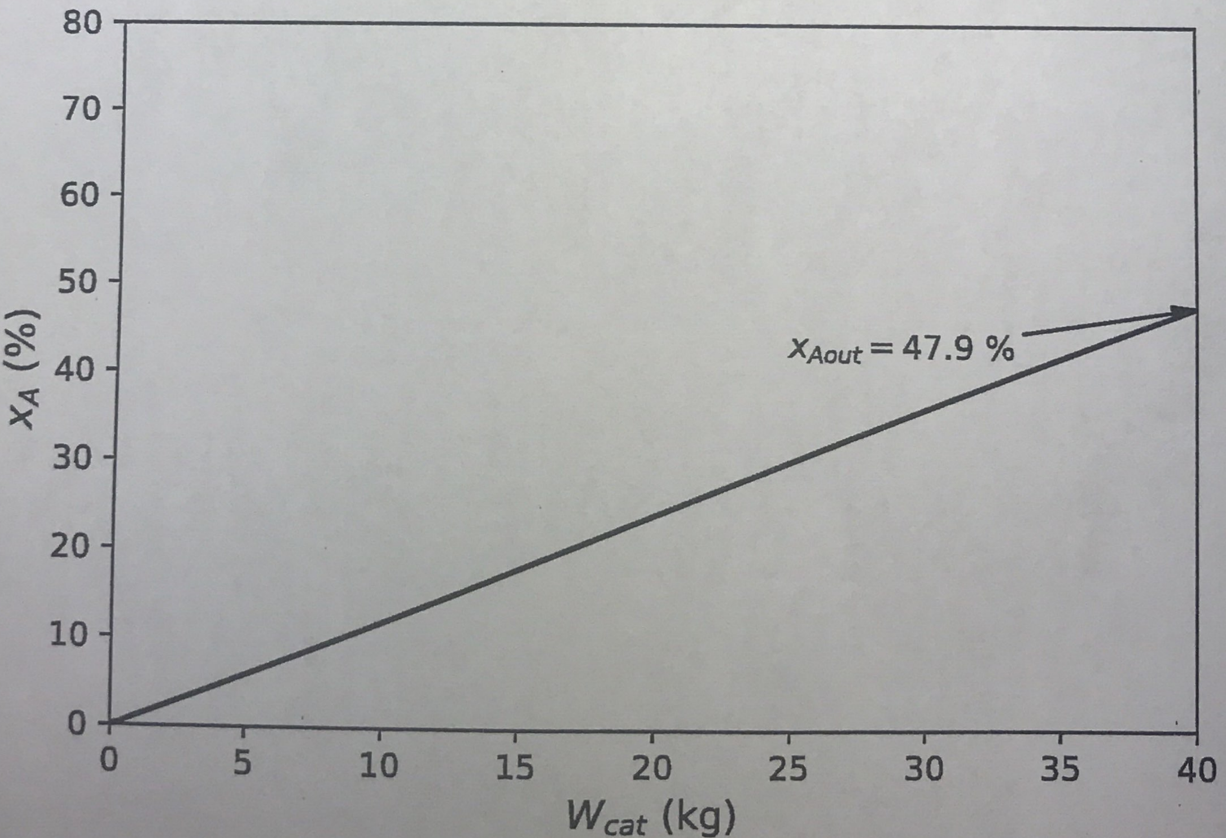

Figure 2: Conversion of component A in PBR reactor in Question 2