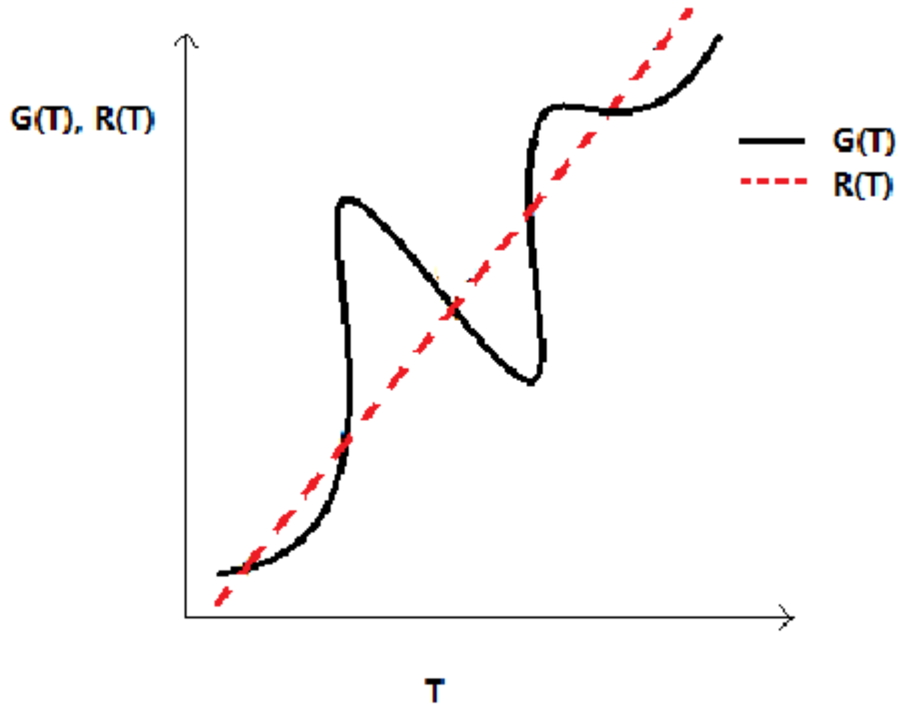
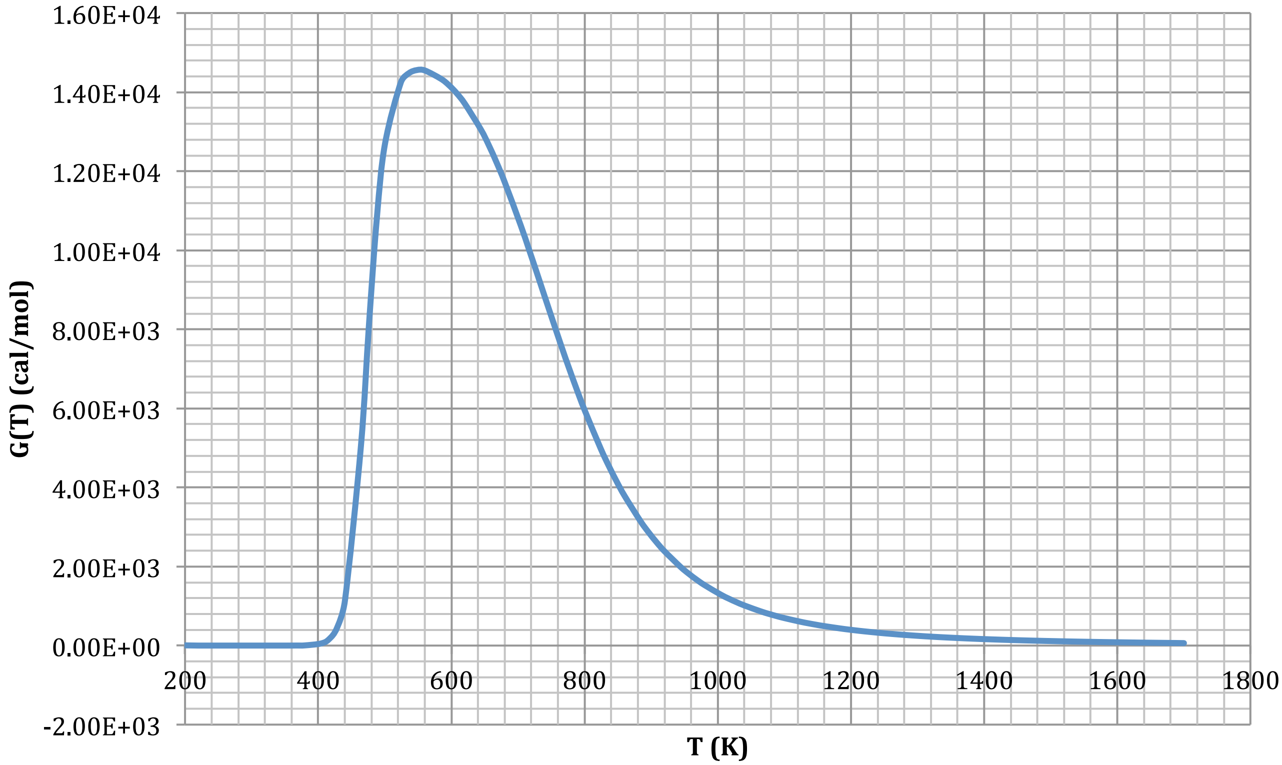
CBE 142 Midterm 2 Draft

1.
A non-ideal steady state, wall-cooled reactor is described by the G(T) and R(T) curves below.
Indicate the steady state by clearly numbering each one. Determine the stability of each steady state and justify your choices in one sentence. Assume that the heat of reaction and heat capacities are independent of temperature. (10 points)



2.

The reversible elementary liquid-phase reaction A↔B is carried out in aCSTR with heat exchanger. Pure species A enters the reactor. (25 points)



Additional information

CPA=CPB=5cal/mol/K, heat capacities are NOT dependent of temperature

FA0=300mol/h

ΔHRX=-15000 cal/mol at 300K

(a) Initial inlet feed temperature is 460K, ambient temperature is fixed at 260K, UA=1500cal/(K*h), please draw clearly label R(T) on the plot using a SOLID LINE.

(b) If you increase the inlet temperature from 460K to 1020 K when everything else is fixed, draw the new R(T) on the plot using DASHED LINE (- - - - -).

(c) Now you can change UA of the heat exchanger. The initial inlet feed temperature is still 460K and ambient temperature is fixed at 260K. What is the maximum possible conversion and what's the corresponding UA value at this maximum conversion? What is the reactor temperature at this maximum conversion? Plot R(T) at this condition using PLUS LINE (+++++)

3.

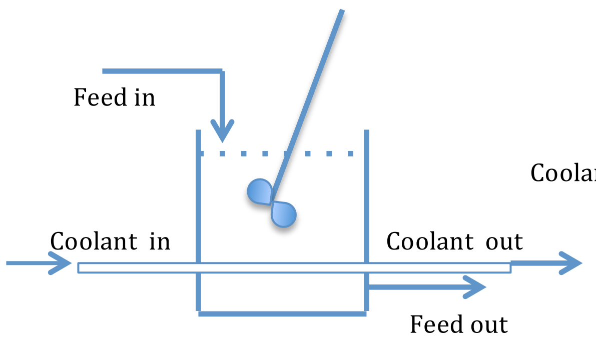
The following irreversible exothermic liquid-phase reaction occurs in a well-stirred steady-state CSTR operating isothermally at 900K.

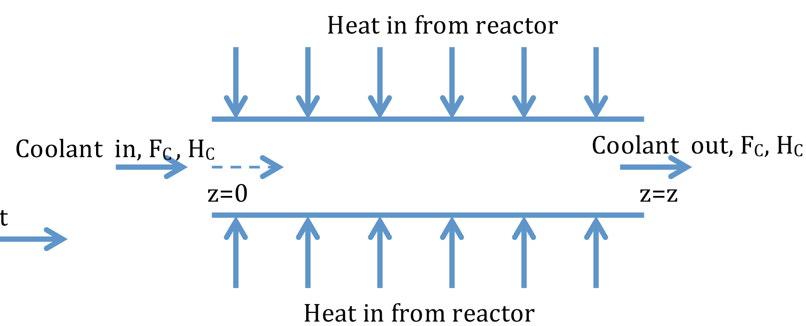
$$2A \rightarrow B, \; r_A \text{ (mol/liter-hr)} = -C_A^2 \text{ at 900 K}$$

A coil runs within the CSTR through which the coolant C flows and removes heat from the reactor. Assume steady state operation of the cooling coil, so that the temperature does not change with time in the cooling coil. Assume this cooling coil unit provides the only communication between the reactor and its surroundings. The volume of fluid in the reactor is constant at 500 liters. Assume that all liquids are incompressible and at the same constant density. (40 points)

Additional Information:

$H_A(T_R)$= -10 kJ/mol, $H_B(T_R)$ = -40 kJ/mol, T_R = 298 K
C_{pA} = 10 J/mol-K, C_{pB} = 20 J/mol-K
C_{pC} for coolant = 4.2kJ/kg-K, Mass flow rate of coolant, $\dot{m}_C$ = 30 kg/hr
Cross-sectional area of the cooling coil, A_C = 0.01 m^2, Ua=60 kJ/(m^3-hr-K)
Inlet temperature of coolant, $T_{am,0}$= 300K





a) Determine the total heat generated in the CSTR per unit time ($\dot{Q}_{gen}$, units: kJ/hr) due to the exothermic reaction. F_{AO}= 1000mol/hr, v_o=1000 liter/hr.

b) The cooling coil has a plug-flow profile for fluid flow and a temperature distribution from inlet to outlet. Perform a steady-state energy balance on a small volume of the cooling coil to obtain an expression for $\frac{dT_{am}}{dz}$, where z is the axial length along the tube. Assume that there are no radial temperature gradients in the cooling tube.

c) Express the coolant temperature T_{am} explicitly as a function of z.

d) Find the total length of the cooling tube required in order to maintain isothermal operation of the CSTR.

e) What is the average temperature T_{am} in the coil? No need to calculate the final numerical value. Keep all the terms as symbols.

4.

The 0th-order irreversible reaction $A \rightarrow B$ is carried out in an unspecified steady-state flow reactor with negligible shaft work. The reaction rate is $-r_A = k$, where k has Arrhenius behavior. (25 points)

a) Assume that $E_a \ll RT$. Write two expressions for the conversion as a function of temperature, one from the mole balance and one from the energy balance. Your expressions can include feed data, reactor volume, thermodynamic constants, Arrhenius constants, and $\dot{Q}$.

b) If the reactor is adiabatic what are the outlet temperature and conversion? The reactor volume is 100L. The feed consists of pure A at a rate of $30\frac{mol}{min}$ and a temperature of 300K. We also know that $C_{P_A} = C_{P_B} = 15\frac{J}{mol\cdot K}$ and $\Delta H_{RX}(1264K) = -6700\frac{J}{mol}$. Also the Arrhenius pre-exponential, A, has a value of $0.25\frac{mol}{L\cdot min}$.

c) Sketch a plot of the energy balance and the mole balance on the same X vs. T graph for the case where $E_a \ll RT$. Label the x- and y-coordinates of the steady-state point. Also clearly label all slopes, and x- and y-intercepts.

d) We have only said that this reactor is a flow reactor. In this case why does the specific reactor type not matter? Explain in one sentence.