Chemical Engineering 140
Midterm Exam
Monday, February 22, 2021 3:05 pm-3:55 pm

*The exam is **120** points total*

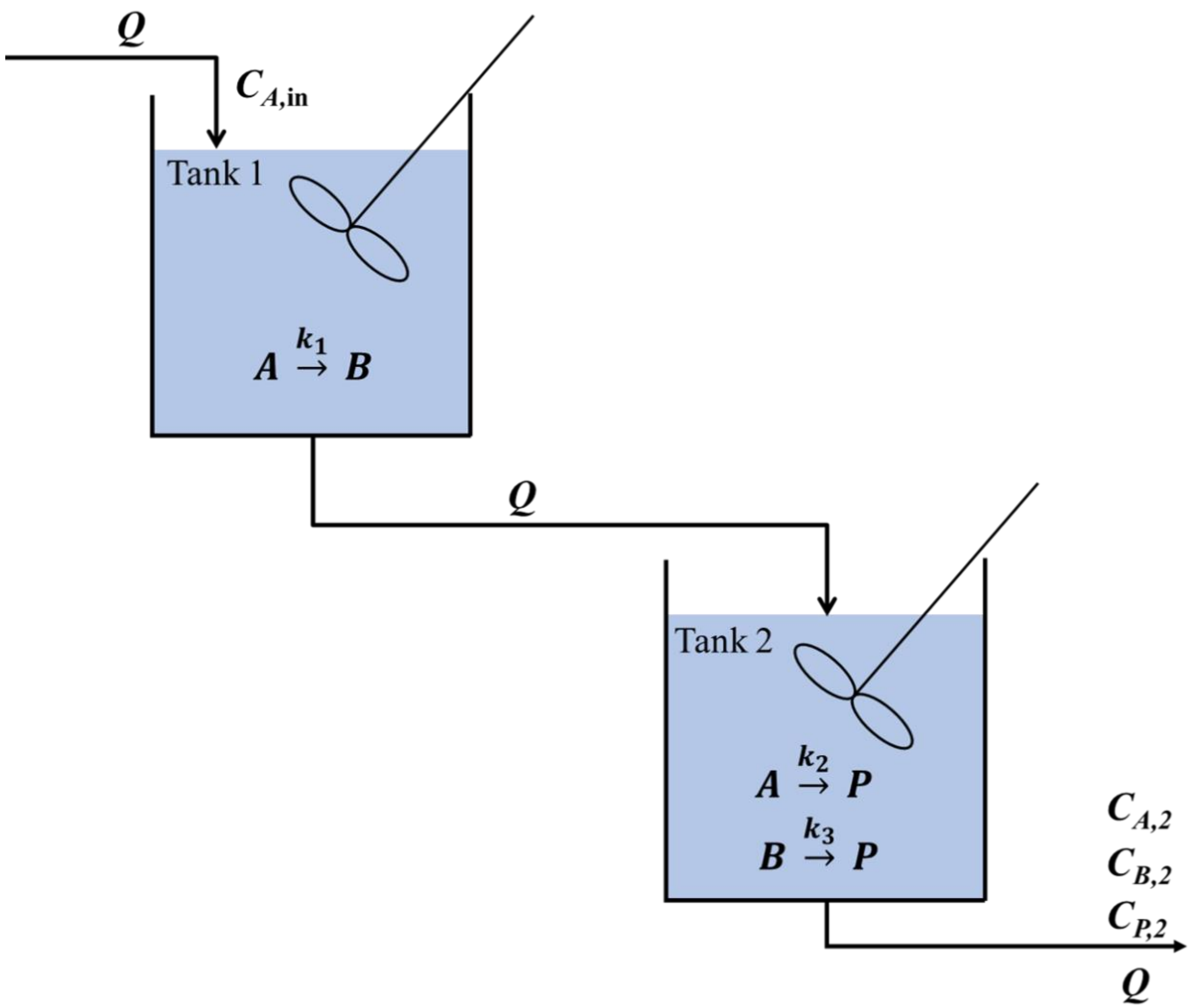
The exam is open note and book but is NOT open internet and should be taken individually.

The exam should have **3** pages including the cover page.

Instructions:

1. Write your solutions on blank sheets of white paper. Box all of your answers. Use a separate sheet/s for problems 1 and 2.
2. On the first sheet of your exam, write your **name** and **student ID and leave it blank**.
3. Use calculators when necessary, and write down the answers in numbers with appropriate units. If you are unable to solve for the final values, show your work with expressions.
4. State all assumptions you deem appropriate to solve the problem, but justify them.
5. Copy down the UC Berkeley honor code statement below and sign it:
   As a member of UC Berkeley, I act with honesty, integrity, and respect for others.

Problem 1 (60 pts)

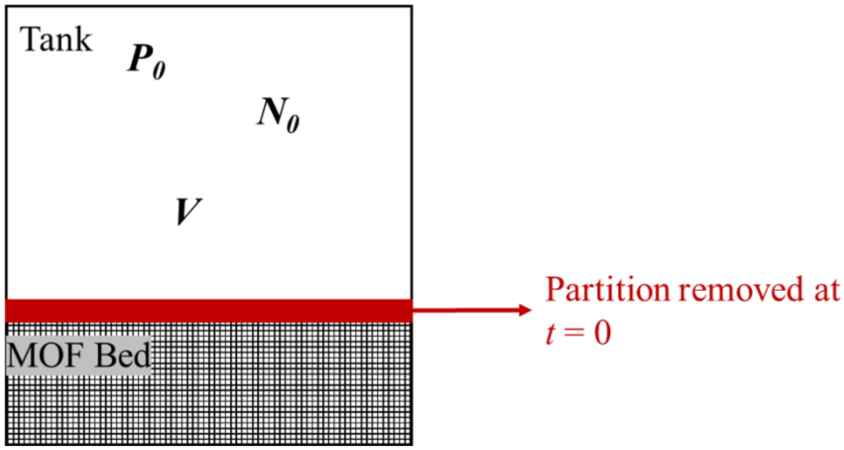


Consider two continuous stirred tank reactors (CSTRs) in series at steady state as shown above with corresponding chemical reactions involving species *A*, *B*, and *P*. The two tanks have the same volume V. Given the following information, determine $C_{A,2}$, $C_{B,2}$, and $C_{P,2}$ in the outlet stream of tank 2 in mol/L:

$C_{A,\text{in}}$ = 2 mol/L
$k_1 = 1\ s^{-1}$
$k_2 = 2\ s^{-1}$
$k_3 = 3\ s^{-1}$
$\tau = V/Q = 1$ s

Problem 2 (60 pts)

Methane is often trapped with crude oil and released during oil drilling. Because methane is a useful energy source and a harmful greenhouse gas, the methane released during drilling is stored in a large, rectangular storage tank. Once this tank is full, the contents of the tank are exposed to a bed of metal—organic frameworks (MOFs) to adsorb the methane.



The tank at time $t = 0$ contains methane gas at a pressure P_0, in a volume V at temperature T = 300K, and contains 75 kilomoles of methane. The partition is removed at $t = 0$ and methane is adsorbed into the MOF, where the net molar rate of adsorption in **moles/second** is given by a simplified version of Langmuir kinetics:

$$\dot{G}_i = k * b * P,$$

where k and b are both constants, and P is the current pressure in the tank. **Keep in mind that $\dot{G}_i$ is in moles/second when using it.** Assume the ideal gas law applies for the gas in the tank, and that the process is isothermal. Also, assume that the volume available for methane in the gas phase is the same before and after the partition is removed. Given the following information,

N_0 = 75 kmol
P_0 = 187 kPa
V = 1,000 m^3
T = 300 K

k = 2 s^{-1}
b = 0.5 mol/Pa
R = 8.314 $m^3 \cdot Pa/mol \cdot K$

a. Derive an expression for $n_{MOF}(t)$, the moles of methane gas adsorbed by the MOF as a function of time.

b. The MOF can adsorb up to 5mmol of methane per gram of MOF and the bed contains 10,000 kg of MOF. Sketch a plot of $n_{MOF}(t)$, then calculate the time at which the MOF reaches capacity.

c. What is the pressure of methane in the tank when the MOF has reached capacity?

This is a very crude model, but hopefully provides a working understanding of adsorption of methane by a MOF.