5

Question 1: [7 points]

(a) **[5 pts]** Fill in the space:

Ligase.

1- The class of enzyme that catalyzes the reaction $(A + B + E \rightarrow AB + E)$ is called

Combination →.

2- HaloEnzyme refers to enzyme-cofactor complex, and the inactive form of the enzyme-cofactor complex for a specific reaction is called ApoEnzyme.

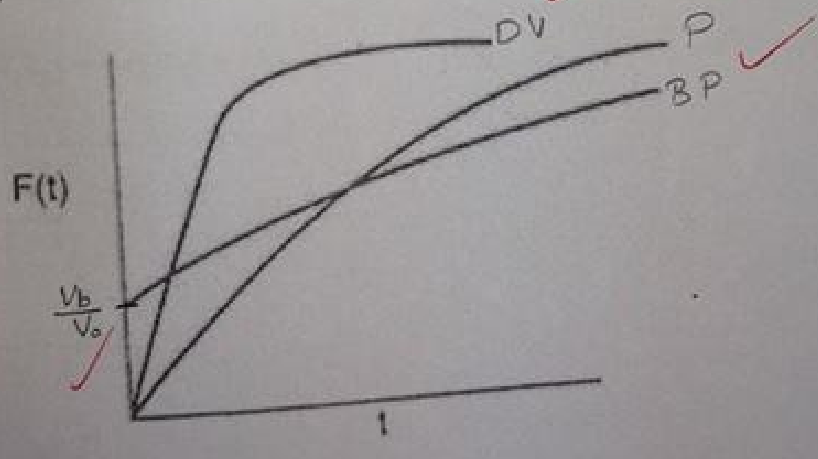
3- The following reaction steps describe the Uncompetitive enzyme inhibition.

$$\boxed{\begin{array}{l} E + S \Leftrightarrow E{\bullet}S \\ E{\bullet}S \rightarrow P + E \\ I + E{\bullet}S \Leftrightarrow I{\bullet}E{\bullet}S \end{array}}$$

4- One drawback to the step injection technique is needs alarge amount of tracer so if the tracer was expensive → using of pulse injection is better.

5- Only for ____________ reactions, knowledge of the RTD is sufficient to predict conversion.

(b) **[2 pts]** The figure below shows a comparison of F(t) for CSTR under perfect operation (P), bypassing (BP), and dead volume (DV). The labeling is missing! Label each curve with the correct abbreviation (P, BP, and DV), and show where $\frac{v_b}{v_0}$ is located.



Question 3: [10 points]

$\boxed{2.5}$

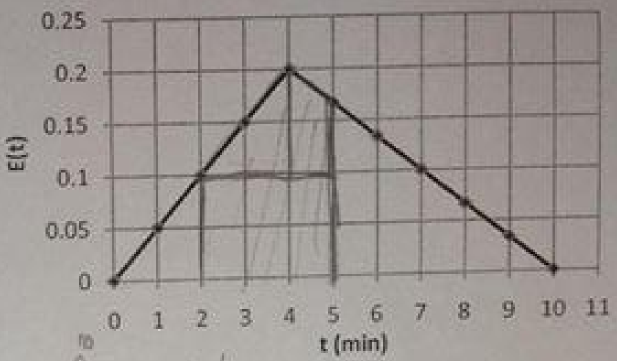
An isothermal pulse test on a piece of reaction equipment gave the following results: The output concentrations rose linearly from zero to 0.5 mmol/L in 5 minutes, and then fell linearly to zero in 10 minutes ager reaching the maximum value.

The RTD resulted from this experiment is as shown:

$E(t) = 0.05t$ for $0 < t < 4$ min

$E(t) = (1-0.1t)/3$ for $4 < t < 10$ min

$E(t) = 0$ for $t > 10$ min



(a) What is the mean residence time t_m? $t_m = \int_0^{10} t \cdot E(t)\,dt$

(b) What fraction of the material spends between 2 and 5 min in the reactor?

The second order liquid phase reaction 2A → B is carried out in the system.

The entering concentration is 2 mol/L and the specific reaction rate (k) is 0.2 L/(mol . min).

(c) For this reaction, what is the conversion after 8 minutes in an ideal batch reactor?

(d) What is the conversion predicted by the segregation model?

t	E(t)	t.E(t)
0	0	0
1	0.05	0.05
2	0.1	0.2
3	0.15	0.45
4	0.2	0.8
5	0.167	0.835
6	0.133	0.798
7	0.1	0.7
8	0.067	0.536
9	0.033	0.297
10	0	0
11	0	

$$\bar{X} = \int_0^{\infty} X(t)\,E(t)\,dt$$

$$= \int \frac{kC_0 t}{1+kC_0 t}$$

$$N_0 \frac{dx}{dt} = -r_A V$$

$$C_{A0} \cancel{V} \frac{dx}{dt} = k C_{A0}^2 (1-x)^2 \cancel{V}$$

$$\int \frac{1}{(1-x)^2}\,dx = \int k C_{A0} \cancel{V}\,dt$$

$$\frac{dx}{dt} = kC_0 (1-x)^2$$

$$\int \frac{1}{(1-x)^2}\,dx = \int kC_0\,dt = kC_0 t$$

$$AUC = \int_0^{10} t.E(t)\,dt = \frac{1}{2} \cdot 10 \cdot 0.835 \quad \boxed{= 0.762}$$

$$= 4.175$$

$t_m = 4.175$

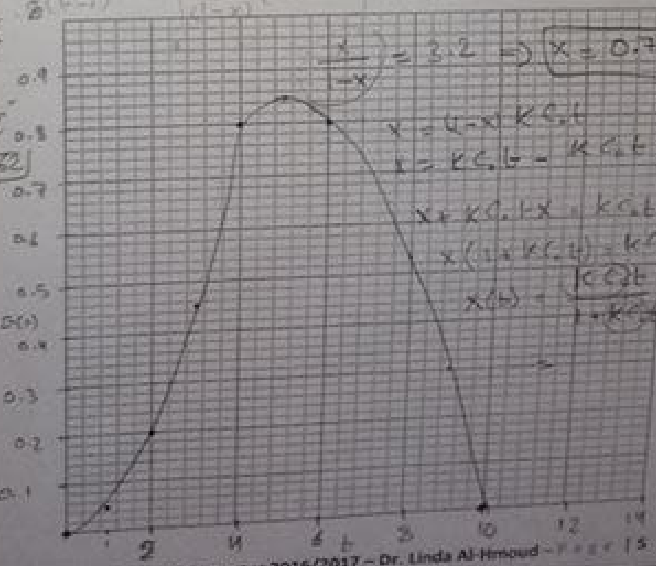
or from integration

$$t_m = \int_0^4 t.(0.05t)\,dt + \int_4^{10} t.\frac{(1-0.1t)}{3}\,dt$$

$$= 1.067 + 3.6$$

$$= 4.67$$

✓



$$\frac{x}{1-x} = 3.2 \Rightarrow \boxed{x = 0.762}$$

$$x = (1-x)\,kC_0 t$$

$$x = kC_0 t - kC_0 t\,x$$

$$x + kC_0 t\,x = kC_0 t$$

$$x(1+kC_0 t) = kC_0 t$$

$$x(t) = \frac{kC_0 t}{1+kC_0 t}$$

B. **[6 points]** If the reaction $2N_2O_5 \rightarrow 4NO_2 + O_2$ follows the following mechanism, *where NO_3 and NO are active intermediates:*

$$N_2O_5 \xrightarrow{k_f} NO_2 + \underline{NO_3}$$
$$NO_2 + NO_3 \xrightarrow{k_b} N_2O_5$$
$$NO_3 + NO_2 \xrightarrow{k_2} \underline{NO} + NO_2 + O_2$$
$$NO_3 + NO \xrightarrow{k_3} 2\,NO_2$$

5.5/

Use the pseudo-steady-state-hypothesis to derive the rate law (r_{O_2}).

$$r_{O_2} = k_2\,[NO_3]\,[NO_2] \checkmark$$

$$r_{NO_3} = k_f\,[N_2O_5] - k_b\,[NO_2]\,[NO_3] - k_2\,[NO_3]\,[NO_2] - k_3\,[NO_3]\,[NO] = 0$$

$$[NO_3] = \frac{k_f\,[N_2O_5]}{k_b[NO_2] + k_2[NO_2] + k_3[NO]}$$

$$r_{NO} = k_2\,[NO_3]\,[NO_2] - k_3\,[NO_3]\,[NO] = 0$$

$$[NO] = \frac{k_2\,[NO_3]\,[NO_2]}{k_3\,[NO_3]}$$

[illegible]

$$[NO] = \frac{k_2\,k_f\,\cancel{[N_2O_5]}\,[NO_2]\,\cancel{(k_b[NO_2] + k_2[NO_2] + k_3[NO])}}{\cancel{(k_b[NO_2] + k_2[NO_2] + k_3[NO])} \cdot k_3 \cdot \cancel{k_f[N_2O_5]}}$$

$$[NO] = \frac{k_2}{k_3}\,[NO_2]$$

$$\Rightarrow r_{O_2} = \frac{k_2\,k_f\,[N_2O_5]\,[NO_2]}{k_b\,[NO_2] + k_2[NO_2] + \frac{\cancel{k_3}\,k_2}{\cancel{k_3}}\,[NO_2]}$$

$$r_{O_2} = \frac{k_2\,k_f\,[N_2O_5]\,\cancel{[NO_2]}}{k_b\,\cancel{[NO_2]} + 2\,k_2\,\cancel{[NO_2]}} \checkmark$$

⁂

$\boxed{11.5}$

Question 2: [13 points]

A. **[7 points]** The enzymatic hydrolysis of starch was carried out with and without $\boxed{\text{maltose}}$ added. Enzyme.

6/

Starch → α-dextrin → Limit dextrin → Maltose

The following data were obtained:

No Inhibition		Maltose Inhibition (I = 12.7 mg/L)	
C_S (g/L)	$-r_S$ (relative)	C_S (g/L)	$-r_S$ (relative)
12.5	100	10	77
9.0	92	5.15	56
4.25	70	2.0	30
1.0	29	1.67	26

(a) Calculate V_{max} and the Michaelis-Menten constant K_M for starch hydrolysis

(b) Using Lineweaver-Burk plot $\left(\frac{1}{-r_S}\ vs.\ \frac{1}{C_S}\right)$, determine the type of maltose inhibition, then calculate K_I.

$$-r_s = \frac{V_{max} \cdot C_s}{K_m + C_s} \rightarrow \frac{1}{-r_s} = \underbrace{\frac{K_M}{V_{max}}}_{\text{slope}} \cdot \frac{1}{C_s} + \underbrace{\frac{1}{V_{max}}}_{\text{intercept}}$$

$\frac{1}{C_s}$	$\frac{1}{-r_s}$
8	0.010
11	0.011
0.235	0.014
1	0.034

$\Rightarrow \frac{1}{V_{max}} = 0.008 \rightarrow \boxed{V_{max} = 125}$ ✓

$\text{slope} = \frac{\Delta y}{\Delta x} = \frac{0.034 - 0.008}{1 - 0} = 0.026$

$\text{or}\ \frac{\Delta y}{\Delta x} = \frac{0.026 - 0.02}{0.7 - 0.46} = 0.025 \Rightarrow \frac{K_M}{125} = 0.025 \rightarrow \boxed{K_M = 3.125}$ ✓

$\frac{1}{C_s}$	$\frac{1}{-r_s}$
0.1	0.013
0.194	0.018
0.5	0.033
0.599	0.038

Same intercept $\Rightarrow \boxed{\text{Competitive}}$ ✓

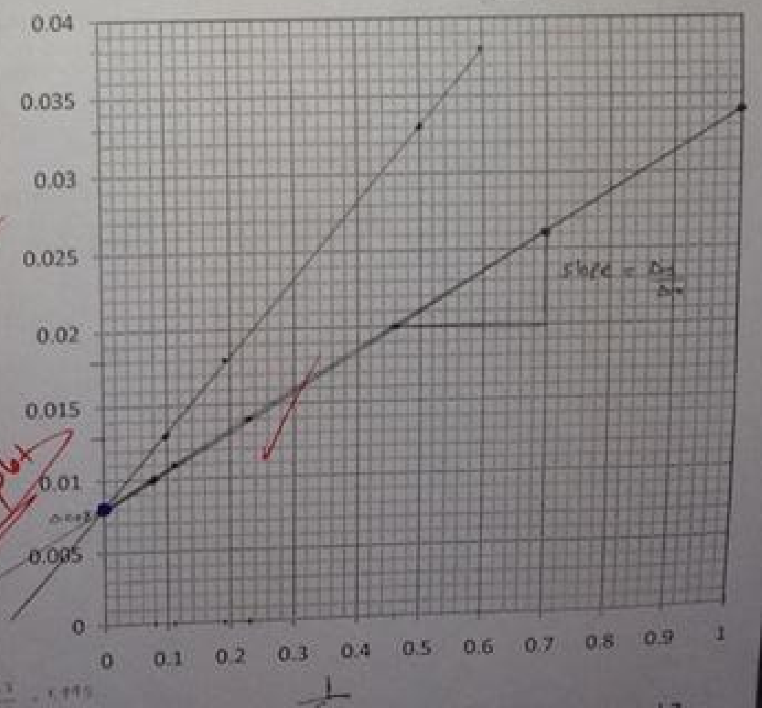
$$-r_s = \frac{V_{max} \cdot C_s}{C_s + K_M\left[1 + \frac{I}{K_I}\right]}$$

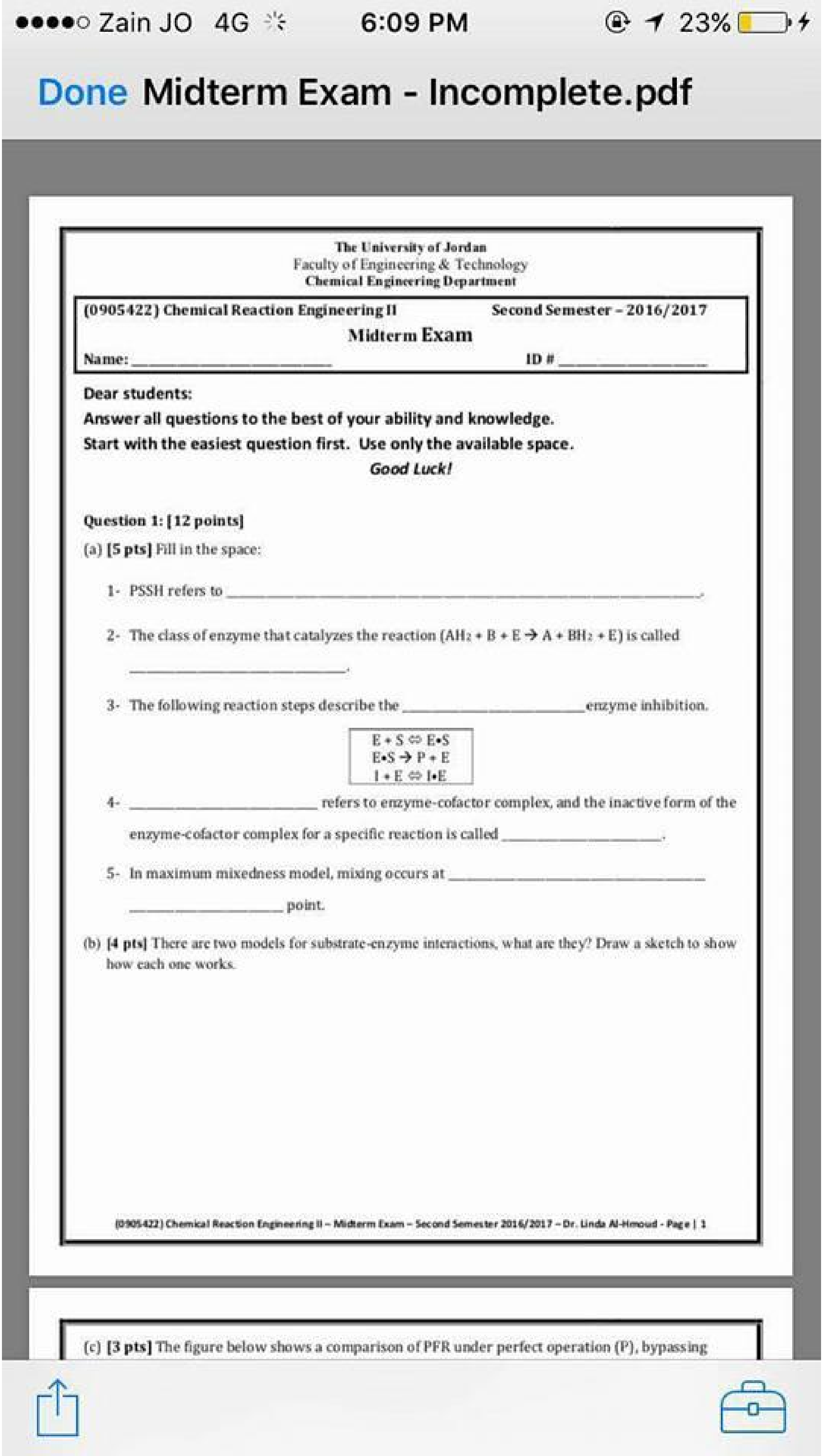
$$77 = \frac{125 \times 10}{10 + 3.125\left[1 + \frac{12.7}{K_I}\right]}$$

$\Rightarrow \boxed{K_I = 12.766}$ o.k

use the plot

$10 + 3.125\left(1 + \frac{12.7}{K_I}\right) = 16.238 \rightarrow 1 + \frac{12.7}{K_I} = 1.995$





The University of Jordan
Faculty of Engineering & Technology
Chemical Engineering Department

(0905422) Chemical Reaction Engineering II **Second Semester – 2016/2017**

Midterm Exam

Name: ______________________ **ID #** ________________

Dear students:

Answer all questions to the best of your ability and knowledge.

Start with the easiest question first. Use only the available space.

Good Luck!

Question 1: [12 points]

(a) **[5 pts]** Fill in the space:

1- PSSH refers to ____.

2- The class of enzyme that catalyzes the reaction ($AH_2 + B + E \rightarrow A + BH_2 + E$) is called

________________________.

3- The following reaction steps describe the ____________________ enzyme inhibition.

$$\boxed{\begin{array}{c} E + S \Leftrightarrow E{\bullet}S \\ E{\bullet}S \rightarrow P + E \\ I + E \Leftrightarrow I{\bullet}E \end{array}}$$

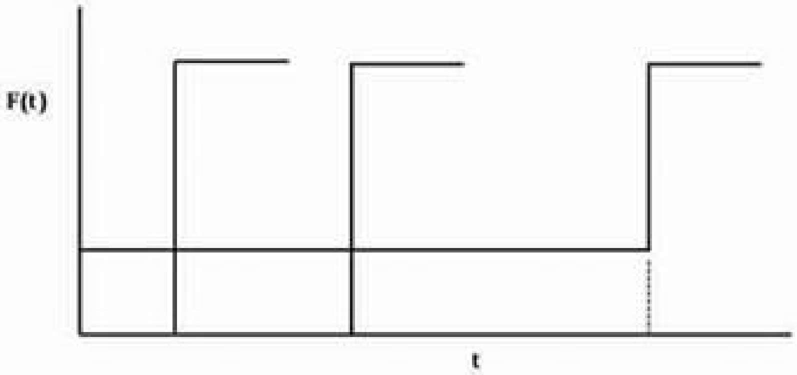
4- ________________________ refers to enzyme-cofactor complex, and the inactive form of the enzyme-cofactor complex for a specific reaction is called ____________________.

5- In maximum mixedness model, mixing occurs at ________________________________ ____________________ point.

(b) **[4 pts]** There are two models for substrate-enzyme interactions, what are they? Draw a sketch to show how each one works.

(c) **[3 pts]** The figure below shows a comparison of PFR under perfect operation (P), bypassing

(c) **[3 pts]** The figure below shows a comparison of PFR under perfect operation (P), bypassing (BP), and dead volume (DV). The labeling is missing!
Label each curve with the correct abbreviation (P, BP, and DV), and show where τ_{SD}, τ_P, and τ_{BP} should be on the x-axis.



Question 2: [9 points]

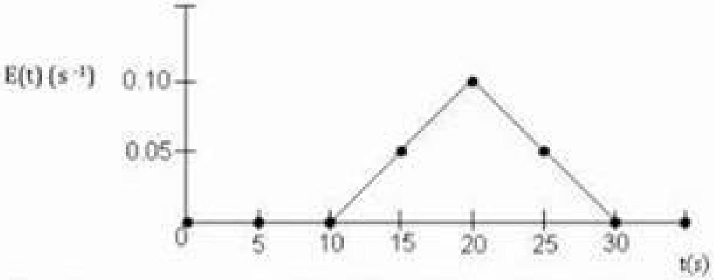
The second order reaction $2A \rightarrow B + C$ occurs in the liquid phase. The RTD function for the reactor in which it is to be carried out is given by

$E(t) = 0$ for $0 < t < 10$

$E(t) = 0.01\,(t-10)$ for $10 < t < 20$

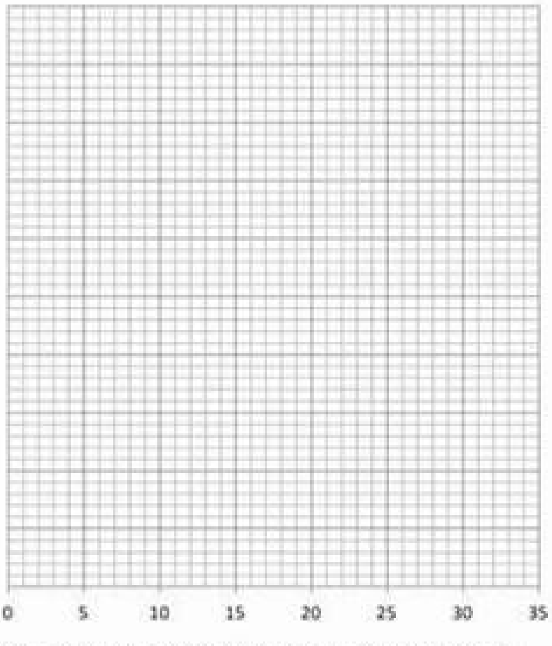
$E(t) = 0.01\,(30-t)$ for $20 < t < 30$

$E(t) = 0$ for $t > 30$



The entering concentration is 2 mol/L and the specific reaction rate is 0.06 L/(mol.s).

(a) What is the mean residence time t_m?
(b) What is the standard deviation σ?
(c) What is the conversion after 30 seconds in a batch reactor?
(d) What is the conversion predicted by the segregation model?



Question 3: [9 points]

Bakers' yeast oxygen uptake is found to follow Michaelis-Menten mechanism, and inhibited by sulfanilamide. The following data were obtained in a particular medium at 23 °C and various oxygen partial pressures:

O_2 partial pressure, P_{O_2} (mm Hg)	O_2 uptake rate (no sulfanilamide) $-r_{O_2}$ (μL O_2/(h.mg cells)	O_2 uptake rate (20 mg sulfanilamide/mL) $-r_{O_2}$, inhibited (μL O_2/(h.mg cells)
0.0	0.0	0.0
0.5	23.5	17.4

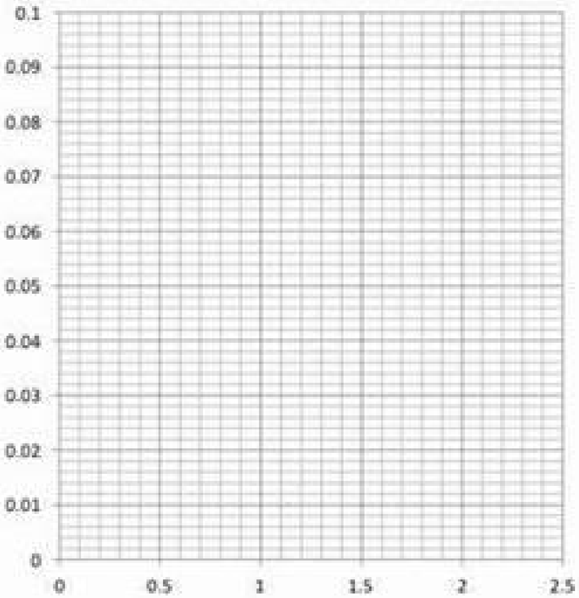
Question 3: [9 points]

Bakers' yeast oxygen uptake is found to follow Michaelis-Menten mechanism, and inhibited by sulfanilamide. The following data were obtained in a particular medium at 23 °C and various oxygen partial pressures:

O_2 partial pressure, P_{O_2} (mm Hg)	O_2 uptake rate (no sulfanilamide) $-r_{O_2}$ (μL O_2/(h.mg cells)	O_2 uptake rate (20 mg sulfanilamide/mL) $-r_{O_2}$, inhibited (μL O_2/(h.mg cells)
0.0	0.0	0.0
0.5	23.5	17.4
1.0	33.0	25.6
2.0	39.0	33.4
4.0	42.0	40.0

(a) Calculate the maximum Q_{O_2} (V_{max}) and the Michaelis-Menten constant K_M.

(b) Using Lineweaver-Burk plot $\left(\frac{1}{-r_S}\ vs.\ \frac{1}{S}\right)$, determine the type of inhibition sulfanilamide that causes the O_2 uptake to change, then find K_I.



Information Sheet

For batch reactor:

$$\frac{dX}{dt} = \frac{-r_A V}{N_{A0}}$$

For moving-bed reactor:

$$-\frac{da}{dW} = \frac{k_d}{U} a^n$$

School of Engineering
Chemical Engineering Department

(30)

(0905422) Chemical Reaction Engineering II **First Semester – 2017/2018**

Midterm Exam

Name: عبدالله الشنواتي **ID #** 0147452

Dear students:

Answer all questions to the best of your ability and knowledge.

Start with the easiest question first. Use only the available space.

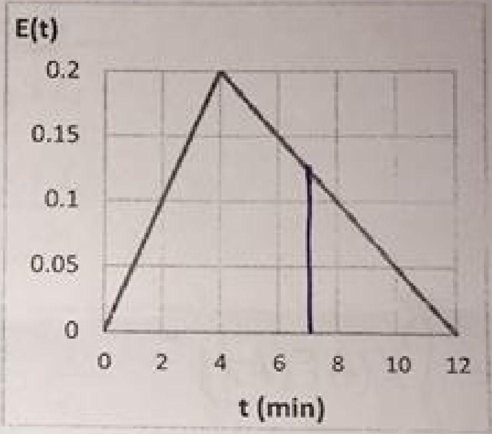
Good Luck!

---

6 **Question 1: [10 points]**

The elementary liquid phase isomerization reaction $A \rightarrow B$ $(k = 0.3\ min^{-1})$ is to be carried out in a continuous flow reactor. Tracer experiments were carried out and found that the reactor has the following RTD

$$E(t) = \begin{cases} \frac{t}{20}, & 0 < t < 4\ min \\ \frac{12-t}{40}, & 4 < t < 12\ min \end{cases}$$



(a) Of what type do you expect this reactor to be?

1.5 (b) Find the fraction of material that spends at least 7 minutes in the reactor.

3 (c) Calculate the mean residence time t_m.

1.5 (d) What is the conversion predicted by the segregation model? (use Simpson's one-third rule)

(a) CSTR because liquid phase

		4	2	4	2	4	2	4	2	4
t	0	1	2	3	4	5	6	7	8	9
E(t)	0	0.05	0.1	0.15	0.2	0.175	0.15	0.125	0.1	0.075
tE(t)	0	0.05	0.2	0.45	0.8	0.875	0.9	0.875	0.8	0.69

0.5

(b) $\int_0^7 E(t)\,dt = \frac{1}{3}\left[0 + 4(0.05) + 2(0.1) + 4(0.15) + 2(0.2) + 4(0.175) + 2(0.15) + 0.125\right]$

$= 0.8416$

?

it's 1 − 0.84

(c) $t_m = \int_0^{12} t E(t)\,dt = \frac{1}{3}\left[0 + 4(0.05) + 2(0.2) + 4(0.45) + 2(0.8) + 4(0.875) + 2(0.9) + 4(0.875) + 2(0.8) + 4(0.675) + 2(0.5) + 4(0.275) + 0\right]$

$= 6.4$ min ✓

Question 2: [9 points] (2) +3.5/

Beef catalase has been used to accelerate the decomposition of hydrogen peroxide to yield water and oxygen. The concentration of hydrogen peroxide is given as a function of time for a reaction mixture with a pH of 6.76 maintained at 30°C.

t (min)	0	2	5	10
$C_{H_2O_2}$(mol/L)	0.10	0.079	0.053	0.025

(a) To what enzyme class does beef catalase belong? α– amyloze

(b) Determine the Michaelis-Menten parameters V_{max} and K_M.

(c) If the total enzyme concentration is tripled;

  (1) how will the values of the parameters V_{max} and K_M change?

  (2) what CSTR residence time (τ) will be required to reduce $C_{H_2O_2}$ from $0.10\ mol/L$ to $0.025\ mol/L$ with triple E_T?

~~$-r_s = \frac{V_{max}[S]}{K_M+[S]}$~~

~~$\frac{1}{-r_s} = \frac{K_M}{V_{max}}\frac{1}{[S]} + \frac{1}{V_{max}}$~~

$$-\frac{dC_s}{dt} = -r_s = \frac{V_{max}C_s}{K_M+C_s}$$

$$-\frac{dt}{dC_s} = \frac{K_M+C_s}{V_{max}C_s}$$

$$\frac{-dt}{dC_s} = \frac{K_M}{V_{max}}\frac{1}{C_s} + \frac{1}{V_{max}}$$

$$-V_{max}\int_0^t dt = \int_{C_{s0}}^{C_s} K_M\frac{1}{C_s}dC_s + \int_{C_{s0}}^{C_s} dC_s$$

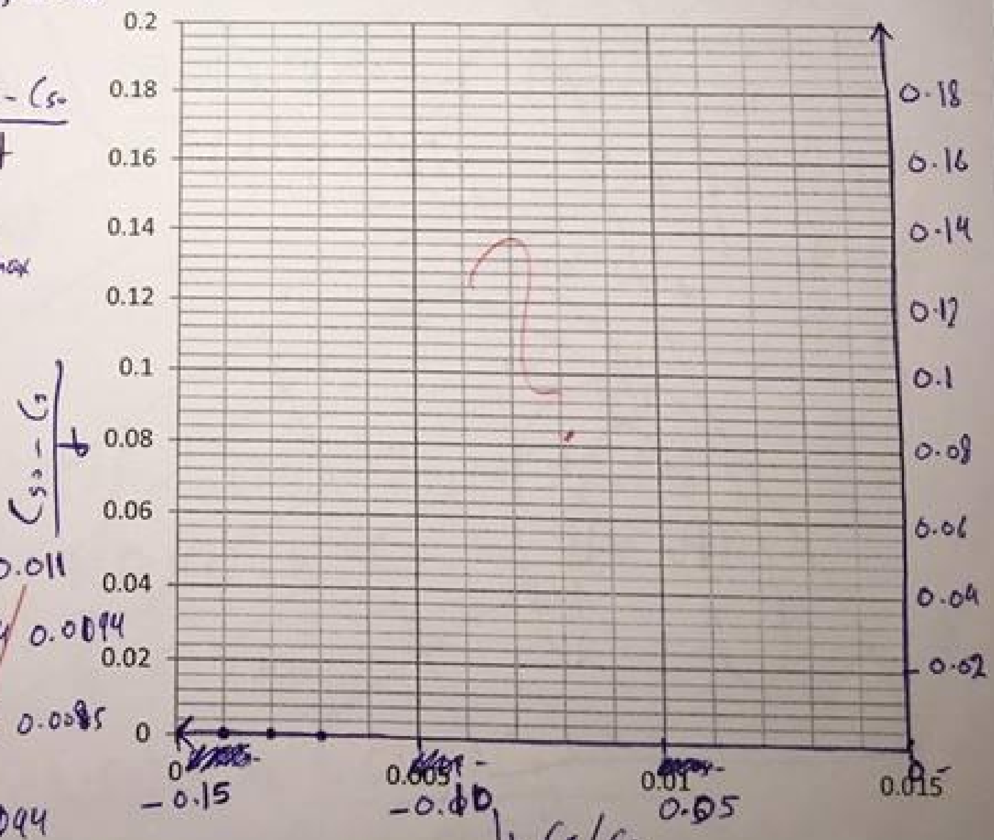
$$-V_{max}t = K_M\ln\frac{C_s}{C_{s0}} + C_s - C_{s0}$$

$$-V_{max} = \frac{K_M}{t}\ln\frac{C_s}{C_{s0}} + \frac{C_s-C_{s0}}{t}$$

$$\frac{C_{s0}-C_s}{t} = \frac{K_M}{t}\ln\frac{C_s}{C_{s0}} + V_{max}$$

$\frac{\ln C_s/C_{s0}}{t}$	$\frac{C_{s0}-C_s}{t}$		
-0.118	0.0105	0.011	0.011
-0.137	9.4×10^{-3}	0.0094	0.0094
-0.138	7.5×10^{-3}	0.0075	0.0085

0.011 0.0094



0.0075

Question 3: [7 points] 1 +2

The rate of the reversible reaction A + B ↔ C has been studied. Experimental data show that the rate of this reaction is

$$r_C = \frac{k_1 C_A C_B - k_2 C_C}{K + C_B}$$

(a) Suggest a mechanism consistent with the rate law.
(b) Sketch the reaction pathways that represent your mechanism.

$A + B \longrightarrow A\cdot \quad A\cdot \longrightarrow A + B$
$C \longrightarrow A\cdot$
$A\cdot \longrightarrow C$

$A + B \rightleftharpoons A\cdot$
$A\cdot \rightleftharpoons C$

2

~~ⓐ $A + 2B \longrightarrow A\cdot + B$~~
~~$B + A\cdot \longrightarrow A + B$~~
~~$C \longrightarrow A\cdot$~~
~~$A\cdot \longrightarrow C$~~

~~$A + 2B \rightleftharpoons A + B$~~
~~$A\cdot \rightleftharpoons C$~~

~~$A + B \longrightarrow A\cdot$~~
~~$A\cdot + B \longrightarrow$~~
~~$A\cdot$~~

~~$A + B \longrightarrow A\cdot$~~
~~$A\cdot \longrightarrow A + B$~~
~~$C \longrightarrow A\cdot + B$~~
~~$B + A\cdot \longrightarrow C$~~

~~$A + B \rightleftharpoons A\cdot + B$~~
~~$B + A\cdot \rightleftharpoons C$~~
~~$A + B \longrightarrow A + B$~~
~~$B + A\cdot \longrightarrow A + B$~~
~~$C \longrightarrow A\cdot + B$~~
~~$B + A \longrightarrow C$~~

~~$-r_{C_3} = k_3[C]$~~

~~$+r_{C4} = k_4[A\cdot]$~~

~~$r_C = -k_3[C] + k_4[A\cdot]$~~

~~$r_{A\cdot 1} = k_1[A][B]^2$~~
~~$-r_{A\cdot 2} = k_2[B][A\cdot]$~~
~~$r_{A\cdot 3} = k_3[C]$~~
~~$-r_{A\cdot 4} = k_4[A\cdot]$~~

~~$A + B \rightleftharpoons A\cdot + B$~~
$C \longrightarrow A\cdot + B$
$A\cdot \longrightarrow B + A\cdot$

~~$k_1[A][B]^2 - k_2[B][A\cdot] + k_3[C] - k_4[A\cdot]$~~

~~$$[A\cdot] = \frac{k_1[A][B]^2 + k_3[C]}{k_2[B] + k_4}$$~~

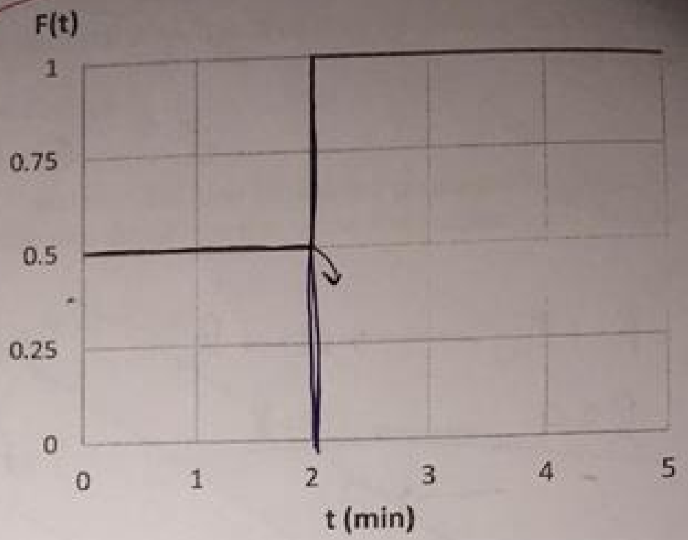
~~$$r_C = -k_3[C] + k_4\,\frac{k_1[A][B]^2 + k_3[C]}{k_2[B] + k_4}$$~~

Question 4: [4 points]

2

There is a 2 m^3 tubular reactor in storage that is to be used to carry out some liquid-phase reaction.

A tracer experiment was carried out with volumetric rate of 1 m^3/min, and reported in terms of F as a function of time in minutes.



(a) Suggest a two-parameter model consistent with the data; the model can consist of ideal reactors, bypass, and dead volume.

(b) Evaluate the model parameters.

(c) **Bonus [3 points]**
Based on your model, evaluate expected conversion if this reactor is used to carry out the liquid-phase second-order reaction A + B → C, where A and B are to be fed in equal molar amounts at a volumetric rate of 1 m^3/min. The entering concentration of A is 2 molar, and the specific reaction rate is 1.5 m^3/(kmol·min).

ⓐ by pass ideal reactor

ⓑ $\frac{v_b}{v_0} = 0.5$

$v_b = 0.5\ m^3/min$

② Dead Volume

volumetric flowrate inlet to reactor = 0.5 m^3/min

$$\tau = \frac{V_{SD}}{v}$$

$$2 = \frac{V_{SD}}{v}$$

$$V_{SD} = 1\ m^3$$

The University of Jordan
Faculty of Engineering & Technology
Chemical Engineering Department

6/10

(0905422) Chemical Reaction Engineering II | Second Semester – 2016/2017

Quiz # 3 (Chapter 10)

Name: [illegible] **ID #** 0136291

The rate law for the catalytic hydrogenation of ethylene (E) to ethane (A) over a cobalt-molybdenum catalyst is

$$-r'_E = \frac{kP_EP_H}{1 + K_EP_E}$$

(a) Write down the reaction stoichiometry.
(b) Suggest a mechanism and rate-limiting step consistent with the rate law.
(c) Knowing that $K_E = 2\ atm^{-1}$ and $P_{E0} = 4\ atm$, what will be the fraction of vacant sites (C_v/C_t) when 40% conversion is achieved?

(a) $E + S \xrightarrow{k_A} A$ [illegible]

OK

(b) mechanism :

$C_{E.S}$ $C_{A.S}$ or $C_T = C_v + C_{A.S} + C_{E}$

* adsorption : $E + S \underset{k_A}{\overset{k_A}{\rightleftharpoons}} E.S$ ✓

* surface rxn : $E + S \underset{k_S}{\overset{k_S}{\rightleftharpoons}} E.S$ ✗ $E.S + S \rightleftharpoons A.S + S$

* desorption : $E.S + H_2 \underset{k_D}{\overset{k_D}{\rightleftharpoons}}$ [illegible] $A + S$ $A.S + H_2 \rightleftharpoons A + S$

* If adsorption rate limiting :

$E + S \underset{k_A}{\overset{k_A}{\rightleftharpoons}} E.S$

$-r_E = k_A P_E C_v - k'_A C_{E.S}$

$-r_E = k_A \left(P_E C_v - \frac{C_{E.S}}{K_A}\right)$

& $\frac{r_S}{k_S} = 0$ & $\frac{r_D}{k_D} = 0$

* rate of surface rxn :

$-r_S = k_S P_E C_v - k'_S C_{E.}$

$-r_S = k_S \left(P_E C_v - \frac{C_{E.S}}{K_S}\right.$

* rate of desorption :

$-r_D = k_D C_{E.S} - k_D P_A C_v$

$-r_D = k_D \left(C_{E.S} - \frac{P_A C_v}{K_D}\right)$

Question 4 [8 points] (4)

The elementary isothermal gas-phase reaction $A \rightarrow B + C$ is carried out in a *moving-bed reactor*. The catalyst decays by sintering (i.e. 2nd order decay $n=2$). The moving bed contains 100 kg W of catalyst and the catalyst flow rate (U_s) through the bed is adjusted so that the **exiting catalytic activity is one-fourth of the entering activity.** $\frac{1}{4} * 0.1$

The specific reaction rate for **fresh catalyst** is 0.10 dm^3 /(kg-cat.s). Pure A enters the reactor at a concentration C_{A0} of 0.005 mol/dm^3 and a **constant volumetric flow rate** of 3.75 dm^3/ s.

(a) Find the catalyst activity as a function of catalyst weight. $a(\omega)$

(b) What will be the exit conversion?

ⓐ
$$\frac{-da}{dW} = \frac{k_d}{U_s} a^n$$

$$\frac{-da}{a^n} = \frac{k_d}{U_s} dw$$

$$\int_0^a \frac{-da}{a^2} = \int_0^w \frac{k_d}{U_s} d\omega$$

$$\frac{1}{a}\Big]_1^a = \frac{k_d}{U_s} \omega \Big|_0^w$$

$$\boxed{a = \frac{U_s}{k_d W}}$$

ⓑ
$$\frac{dx}{dW} = \frac{a(-r_A'(t=0))}{F_{A0}}$$

$$F_{A0} = C_A V = \frac{0.005 \text{ mol}}{\text{dm}^3}\Big|\frac{3.75 \text{ dm}^3}{\text{s}} = 0.01875 \frac{\text{mol}}{\text{s}}$$

$$U_s = \frac{1}{4} * 0.1 = 0.025$$

$$-r_A = k C_A$$

$$C_A = C_{A0}(1-x)$$

$$-r_A = k C_{A0}(1-x)$$

$$\frac{dx}{dw} = \frac{\frac{U_s}{k_d W} * k C_{A0}(1-x)}{F_{A0}}$$

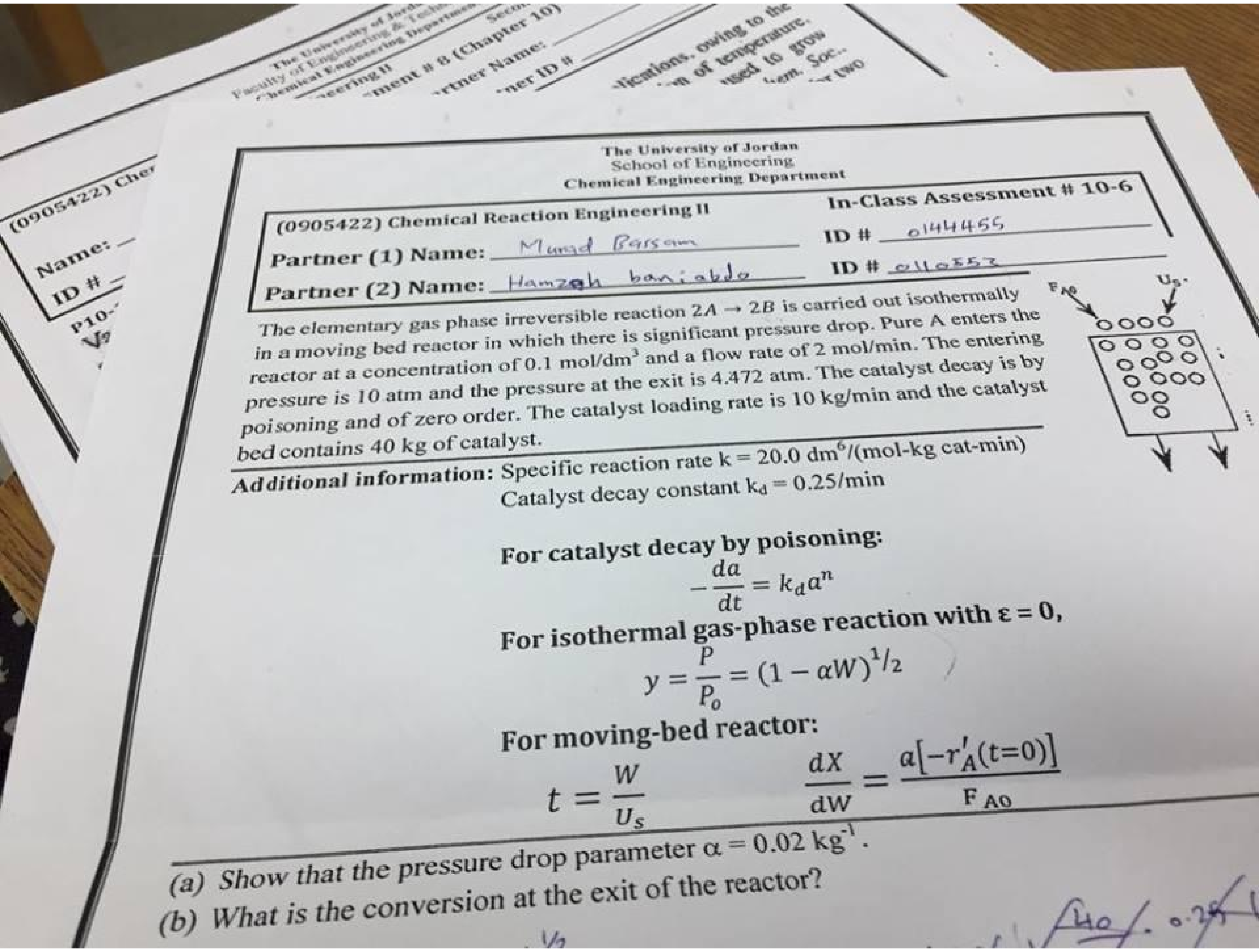
$$\int_0^x \frac{dx}{(1-x)} = \int_0^{100} \frac{U_s * k C_{A0}}{k_d / F_{A0}} * \frac{1}{W} dW$$

$$\ln\frac{1}{1-x} = \int_0^{100} \frac{0.25 * 0.1 * 0.005}{0.01875} * \frac{1}{\omega} d\omega$$

$$\ln\frac{1}{1-x} = 6.67*10^{-3} \int_0^{100} \frac{1}{\omega} dw$$

$$\ln\frac{1}{1-x} = 6.67*10^{-3} \ln\omega \Big|_0^{100}$$

$x = ?$



The University of Jordan
School of Engineering
Chemical Engineering Department

(0905422) Chemical Reaction Engineering II **In-Class Assessment # 10-6**

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The elementary gas phase irreversible reaction $2A \rightarrow 2B$ is carried out isothermally in a moving bed reactor in which there is significant pressure drop. Pure A enters the reactor at a concentration of 0.1 mol/dm^3 and a flow rate of 2 mol/min. The entering pressure is 10 atm and the pressure at the exit is 4.472 atm. The catalyst decay is by poisoning and of zero order. The catalyst loading rate is 10 kg/min and the catalyst bed contains 40 kg of catalyst.

Additional information: Specific reaction rate k = 20.0 dm^6/(mol-kg cat-min)
Catalyst decay constant k_d = 0.25/min

For catalyst decay by poisoning:

$$-\frac{da}{dt} = k_d a^n$$

For isothermal gas-phase reaction with ε = 0,

$$y = \frac{P}{P_o} = (1 - \alpha W)^{1/2}$$

For moving-bed reactor:

$$t = \frac{W}{U_s} \qquad \frac{dX}{dW} = \frac{a[-r'_A(t=0)]}{F_{A0}}$$

(a) *Show that the pressure drop parameter* $\alpha = 0.02$ kg^{-1}.

(b) *What is the conversion at the exit of the reactor?*

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(0905422) Chemical Reaction Engineering II **First Semester – 2017/2018**

Quiz # 3 (Chapter 10)

Name: ______________________________ **ID #** ____________________

Titanium nitride (TiN) films are used in decorative coatings as well as in wear-resistant tools. There is increasing interest in TiN because of its thermal stability, good diffusion barrier properties, and its low electrical resistivity. Titanium nitride films were formed by chemical vapor deposition (*CVD)* from a mixture of $TiCl_4$, NH_3, H_2 and Ar. The following observations can be made:

- The rate of deposition is independent of Ar and H_2
- At low partial pressures of both $TiCl_4$ and NH_3, the deposition rate appears to be first-order in $TiCl_4$ and second-order in NH_3
- At high partial pressures of NH_3 the rate varies inversely with $TiCl_4$

The following mechanism has been suggested for the reaction:

$$TiCl_4 + 2NH_3 \leftrightarrow TiCl_4(NH_3)_2 \qquad gas\ phase$$

$$TiCl_4(NH_3)_2 + S \leftrightarrow TiCl_4(NH_3)_2 \cdot S$$

$$TiCl_4(NH_3)_2 \cdot S + S \rightarrow TiN + S + gas\ products\ (H_2, HCl, etc.)$$

It is believed that the gas-phase reaction to form the complex $TiCl_4(NH_3)_2$ is in equilibrium.

(a) Determine the rate expression for the suggested mechanism.

(b) Does the rate expression agree with experimental observations? Explain.

(c) What is the observed adsorption method called? ____

(d) What type of surface reaction mechanism is suggested? ________________________________

(e) What linearization will you do to determine the reaction rate parameters?

(f) Use the data below to determine the reaction rate parameters:

r_{Dep} (mol TiN/cm^2. min) × 10^8	15	10	6	8.5	16
P_{NH_3}(mT)	79	79	79	60	10
P_{TiCl_4}(mT)	1	3	10	2.3	2.3