Exam III
Administered: Friday, November 8, 2018
24 points

For each problem part: 0 points if not attempted or no work shown,
1 point for partial credit, if work is shown,
2 points for correct numerical value of solution, if work is shown

Problem 1. (16 points)
Consider a set of three first order reactions occurring in a closed pot (a batch reactor) involving compounds, OX, MX and PX.

number	reaction	rate expression	rate constant
1	OX → MX	$r_1 = k_1 OX$	$k_1 = 3\ s^{-1}$
2	MX → PX	$r_2 = k_2 MX$	$k_2 = 9\ s^{-1}$
3	PX → OX	$r_3 = k_3 PX$	$k_3 = 5\ s^{-1}$

These equations give rise to the following steady state (at infinite time) mass balances.

compound	rate expression
OX	$0 = k_3 PX - k_1 OX$
MX	$0 = k_1 OX - k_2 MX$
PX	$0 = k_2 MX - k_3 PX$

We also recognize that the sum of the mass fractions equal unity.

$$OX + MX + PX = 1$$

Your goal is to find the steady state composition in this reactor. To do so, answer the following questions.
(a) Are these equations linear or non-linear?
(b) Since you have three unknowns, which three of the four equations should be used to solve for the composition?
(c) Construct a matrix, $\underline{\underline{A}}$, and vector, $\underline{b}$, from which the compositions, $\underline{x}$, can be obtained.
(d) Provide the determinant of the matrix.
(e) Provide the rank of the matrix, $\underline{\underline{A}}$.
(f) Provide the rank of the augmented matrix, $\underline{\underline{Ab}}$.
(g) How many solutions will $\underline{\underline{A}}\underline{x}=\underline{b}$ have?
(h) Provide a solution if it exists.

(over)

Problem 2. (8 points)
Consider a set of three reactions occurring in a closed pot (a batch reactor) involving compounds, OX, MX and PX.

number	reaction	rate expression	rate constant
1	$OX+OX \rightarrow MX$	$r_1 = k_1 OX^2$	$k_1 = 3\ s^{-1}$
2	$MX+OX \rightarrow PX$	$r_2 = k_2 OX \cdot MX$	$k_2 = 9\ s^{-1}$
3	$PX \rightarrow 3OX$	$r_3 = k_3 PX$	$k_3 = 5\ s^{-1}$

These equations give rise to the following steady state (at infinite time) mass balances.

compound	rate expression
OX	$0 = 3k_3 PX - 2k_1 OX^2 - k_2 OX \cdot MX$
MX	$0 = k_1 OX^2 - k_2 OX \cdot MX$
PX	$0 = k_2 OX \cdot MX - k_3 PX$

We also recognize that the sum of the mass fractions equal unity.

$$OX + MX + PX = 1$$

Your goal is to find the steady state composition in this reactor. To do so, answer the following questions.
(a) Are these equations linear or non-linear?
(b) Since you have three unknowns, which three of the four equations should be used to solve for the composition?
(c) What solution technique should use you to solve this problem?
(d) Provide a solution.