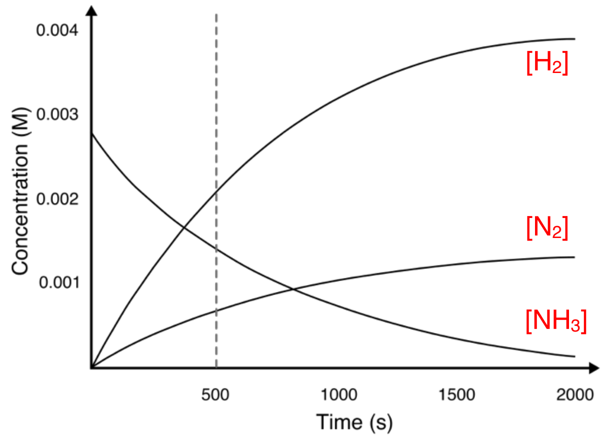
1. Consider the degradation of ammonia gas into nitrogen gas and hydrogen gas.

$$2\ NH_3\ (g) \rightarrow N_2\ (g) + 3\ H_2\ (g)$$



A) For the concentration vs. time plot to the right, label each curve with the appropriate chemical species.

Discuss how you chose each curve.

[NH_3] decreases over time.
[N_2] and [H_2] increase over time.
[H_2] increases more rapidly than [N_2].

B) At t = 500 s, the slope of a line tangent to the NH_3-curve is -1.94×10^{-6} M/s. What is the rate of the reaction at this instant?

Recall that the instantaneous relative rate of the reaction can be expressed as:

$$\text{Rate} = -\frac{1}{2}\frac{\Delta[\text{NH}_3]}{\Delta t} = \frac{\Delta[\text{N}_2]}{\Delta t} = \frac{1}{3}\frac{\Delta[\text{H}_2]}{\Delta t}$$

The slope of the line tangent to the NH_3-curve tells us how [NH_3] changes with time, so the rate is

$$\text{Rate} = -\frac{1}{2}\left(-1.94 \times 10^{-6}\frac{\text{M}}{\text{s}}\right) = 9.70 \times 10^{-7}\frac{\text{M}}{\text{s}}$$

C) Compute the slopes of the tangent lines for the N_2- and H_2-curves at t = 500 s.

The instantaneous slopes will be related by the stoichiometry of the balanced chemical equation. Therefore, the slopes of [N_2] and [H_2] can be related to [NH_3] by

$$\frac{\Delta[\text{N}_2]}{\Delta t} = -\frac{1}{2}\frac{\Delta[\text{NH}_3]}{\Delta t} = 9.70 \times 10^{-7}\frac{\text{M}}{\text{s}} \qquad \frac{\Delta[\text{H}_2]}{\Delta t} = -\frac{3}{2}\frac{\Delta[\text{NH}_3]}{\Delta t} = 2.91 \times 10^{-6}\frac{\text{M}}{\text{s}}$$

2. The overall stoichiometry in parts A and B below is the same, but the rate laws differ.

A) Determine the rate law for the following reaction using the initial rates data.

$$2\ NO\ (g) + O_2\ (g) \rightarrow 2\ NO_2\ (g)$$

Experiment	[NO]₀ (M)	[O₂]₀ (M)	Initial Rate (M/s)
1	0.100	0.100	1.24
2	0.100	0.050	0.62
3	0.050	0.100	0.31

Our rate law will have the form: $\text{Rate} = k[\text{NO}]^a[\text{O}_2]^b$

Compare experiments 1 and 3 to find a, the order of the reaction with respect to [NO].
Compare experiments 1 and 2 to find b, the order of the reaction with respect to [O_2].
Plug in the values from any one experiment (I choose #1) to solve for *k*.

$$\frac{\text{Rate}_1}{\text{Rate}_3} = \frac{k[\text{NO}]_1^a[\text{O}_2]_1^b}{k[\text{NO}]_3^a[\text{O}_2]_3^b}$$
$$\frac{\text{Rate}_1}{\text{Rate}_3} = \frac{[\text{NO}]_1^a}{[\text{NO}]_3^a}$$
$$\frac{1.24\frac{\text{M}}{\text{s}}}{0.31\frac{\text{M}}{\text{s}}} = \left(\frac{0.100\ \text{M}}{0.050\ \text{M}}\right)^a$$
$$4 = 2^a$$
$$a = 2$$

$$\frac{\text{Rate}_1}{\text{Rate}_2} = \frac{k[\text{NO}]_1^a[\text{O}_2]_1^b}{k[\text{NO}]_2^a[\text{O}_2]_2^b}$$
$$\frac{\text{Rate}_1}{\text{Rate}_2} = \frac{[\text{O}_2]_1^b}{[\text{O}_2]_2^b}$$
$$\frac{1.24\frac{\text{M}}{\text{s}}}{0.62\frac{\text{M}}{\text{s}}} = \left(\frac{0.100\ \text{M}}{0.050\ \text{M}}\right)^b$$
$$2 = 2^b$$
$$b = 1$$

$$\text{Rate}_1 = k[\text{NO}]_1^2[\text{O}_2]_1^1$$
$$1.24\frac{\text{M}}{\text{s}} = k(0.100\ \text{M})^2(0.100\ \text{M})^1$$
$$k = 1240\ \text{M}^{-2}\text{s}^{-1}$$

Therefore, $\text{Rate} = k[\text{NO}]^2[\text{O}_2]^1; k = 1240\ \text{M}^{-3}\text{s}^{-1}$

B) Determine the rate law for the following reaction using the initial rates data.

$$2\ NO\ (g) + Cl_2\ (g) \rightarrow 2\ NOCl\ (g)$$

Experiment	$[NO]_o$ (M)	$[Cl_2]_o$ (M)	Initial Rate (M/s)
1	0.200	0.100	0.63
2	0.200	0.300	5.70
3	0.800	0.100	2.58

Our rate law will have the form: $\text{Rate} = k[\text{NO}]^a[\text{Cl}_2]^b$

Compare experiments 3 and 1 to find a, the order of the reaction with respect to [NO].
Compare experiments 2 and 1 to find b, the order of the reaction with respect to $[Cl_2]$.
Plug in the values from any one experiment (I choose #1) to solve for *k*.

$$\frac{\text{Rate}_3}{\text{Rate}_1} = \frac{k[\text{NO}]_3^a[\text{Cl}_2]_3^b}{k[\text{NO}]_1^a[\text{Cl}_2]_1^b}$$

$$\frac{\text{Rate}_3}{\text{Rate}_1} = \frac{[\text{NO}]_3^a}{[\text{NO}]_1^a}$$

$$\frac{2.58\,\frac{\text{M}}{\text{s}}}{0.63\,\frac{\text{M}}{\text{s}}} = \left(\frac{0.800\text{ M}}{0.200\text{ M}}\right)^a$$

$$4 = 4^a$$

$$a = 1$$

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \frac{k[\text{NO}]_2^a[\text{Cl}_2]_2^b}{k[\text{NO}]_1^a[\text{Cl}_2]_1^b}$$

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \frac{[\text{Cl}_2]_2^b}{[\text{Cl}_2]_1^b}$$

$$\frac{5.70\,\frac{\text{M}}{\text{s}}}{0.63\,\frac{\text{M}}{\text{s}}} = \left(\frac{0.300\text{ M}}{0.100\text{ M}}\right)^b$$

$$9 = 3^b$$

$$b = 2$$

$$\text{Rate}_1 = k[\text{NO}]_1^1[\text{Cl}_2]_1^2$$

$$0.63\,\frac{\text{M}}{\text{s}} = k(0.200\text{ M})^1(0.100\text{ M})^2$$

$$k = 320\text{ M}^{-2}\text{s}^{-1}$$

If expt. 2 or 3:
$k = 315\text{ M}^{-2}\text{s}^{-1}$

Therefore, $\text{Rate} = k[\text{NO}]^1[\text{Cl}_2]^2$; $k = 320\text{ M}^{-2}\text{s}^{-1}$ or $315\text{ M}^{-2}\text{s}^{-1}$