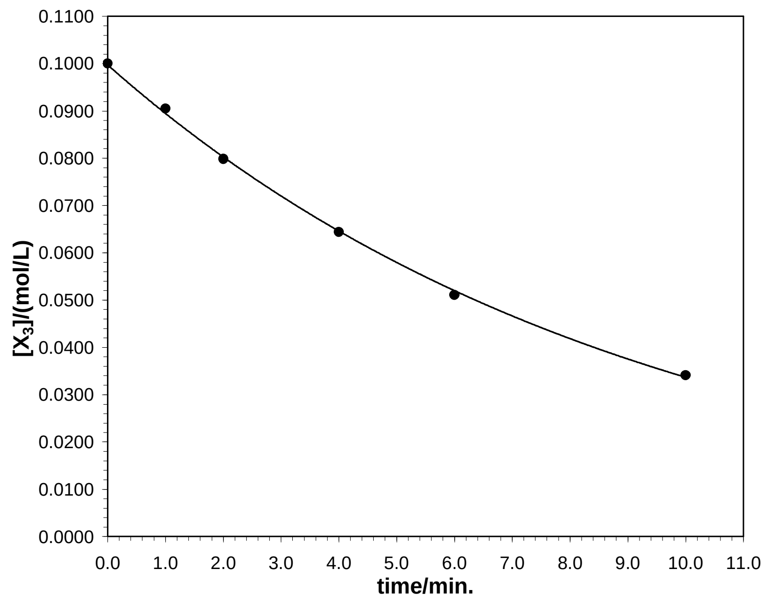
Chemical Kinetics: Problem Set 1 (covering Topic 1)

1. The compound X_3 decomposes according to the reaction equation $2X_3 \rightarrow 3X_2$. A chemist devised an experiment to measure the concentration of X_3 at various times. The following data were obtained (the data in the table are plotted in the graph).

Time/min.	$[X_3]$/(mol/L)
0.0	0.1000
1.0	0.0905
2.0	0.0799
4.0	0.0644
6.0	0.0511
10.0	0.0341



a) Determine the average rate of change in $[X_3]$ over the entire experiment using the information in the data table.
b) Determine the average rate of change in $[X_3]$ between 2.0 and 6.0 minutes using the data table.
c) Using the graph and a straight-edge, estimate the rate of change in $[X_3]$ at exactly 4.0 minutes. How does this compare to the average rate between 2.0 and 6.0 minutes calculated from the data table in (b)?
d) From the graph and a straight-edge, estimate the initial rate of change in $[X_3]$.
e) Which rate of change in $[X_3]$ (in a, b, c, or d) is the largest (most negative)? Why?

2. Write a balanced chemical equation given the following reaction rate expressions:

$$ReactionRate = -\frac{d[C_3H_8]}{dt} = -\frac{1}{5}\frac{d[O_2]}{dt} = \frac{1}{4}\frac{d[H_2O]}{dt} = \frac{1}{3}\frac{d[CO_2]}{dt}$$

3. Ammonia is produced in the chemical industry by the reaction of hydrogen and nitrogen gas:

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

a) Express the rate of the reaction in terms of the change in concentration of each of the reactants and products.
b) If $[NH_3]$ is increasing at a rate of 0.2 mol/L·s, what are $d[N_2]/dt$ and $d[H_2]/dt$? What is the reaction rate?
c) If $[H_2]$ is decreasing at a rate of 0.06 mol/L·s, what are $d[N_2]/dt$ and $d[NH_3]dt$? What is the reaction rate?
d) If N_2 and H_2 are allowed to react in a sealed reaction vessel (so that the volume remains constant), what happens to the overall pressure with time—will it increase or decrease?

CHALLENGE PROBLEM:* A manometer is a device used to measure the overall pressure of a system containing gases. According to the ideal gas law, the concentration of a gas is proportional to its *partial* pressure. This is because if $P_xV=n_xRT$, then $P_x=(n_x/V)RT = [X]RT$, and $[X] = P_x/RT$. So, in principle, partial pressure could be used instead of concentration to measure a reaction rate. Unfortunately, though, a manometer can be used to measure only *overall* pressure, not the pressure of a single gas in a mixture. By expressing the total pressure in the system, P_{total}, as the sum of the partial pressures of products and reactants, along with the fact that [X] for each gas is P_x/RT and a little calculus, see if you can prove that for the ammonia reaction above

$$reaction\ rate = \frac{-1}{2RT}\frac{dP_{total}}{dt}$$

*One bonus point; **all or none; must be done ON YOUR OWN—not at the problem session with the teaching assistant!—must be turned in on a separate sheet of paper directly to your professor.**