Chemical Rates Lab
Notes for Lab Assistants

1. Give students an overview of the three parts of the lab:

Part 1: $[A] \rightarrow [B]$
In this part we set up and solve a system of DEs to describe a one-way chemical reaction.

Part 2: $[A] \rightleftarrows [B]$
In this part we set up and solve a system of DEs to describe a two-way chemical reaction.

Part 3: In this part we look at the equilibrium (or "steady state") that is predicted by these equations.

2. Tell students that there will be notation which may be unfamiliar to them and that the algebra can becoming challenging. They will also, for the first time, be faced with a system of differential equations. Nevertheless, they will actually have to solve only three types of DEs, all of which are listed below. (It will be hard for many students to recognize these DEs in the context of this lab.) Write these on the board and briefly talk about the methods of solving them which they have already learned.

$$\frac{dy}{dt} = ce^{kt} \qquad\qquad \frac{dy}{dt} = ky \qquad\qquad \frac{dy}{dt} = ay + b$$

Comments for lab assistants:

- Students have learned how to solve the first one by antidifferentiation: $y = \frac{c}{k}e^{kt} + C$.

- Students have learned how to solve the second one by recognition: $y = Ce^{kt}$. Note that they have not yet studied separation of variables.

- Students have learned how to solve the third one (remember, no separation of variables yet) by substitution:
  Let $z = ay + b$; then $\frac{dz}{dt} = a\frac{dy}{dt} = az$. It follows (by recognition) that $z = Ce^{at}$. Substituting back into the equation defining z, we get: $Ce^{at} = ay + b$, and we can solve this for y and then apply the initial conditions.

3. The following suggestions to students can help them through the notational difficulties.

$[A](t)$ represents the concentration of chemical A as a function of time t. Just denote this function by [A] to make it easier to read. Similarly you can use [B] to denote $[B](t)$.

Use the symbol A_0 to denote the value of $[A](0)$, the initial value of the function [A]. Similarly use B_0 to denote the value of $[B](0)$.

In part 2, it will make several steps of algebra easier to write and easier to read if you use K for the expression $-k_1 - k_2$, which will appear part way through the working of the problem. Similarly, you can use C to replace the expression $k_2(A_0 + B_0)$ when it appears. Of course, at the end of the work one should eliminate K and C from the answer since they were used only for convenience.

4. Write the following answers on the board:

Part 1 (b): $[\mathrm{B}](t) = -A_0 e^{-k_1 t} + A_0 + B_0$

(e): $\lim_{t\to\infty}[A](t) = 0$; $\lim_{t\to\infty}[\mathrm{B}](t) = A_0 + B_0$

Part 2 (c): $[\mathrm{A}](t) = \frac{k_1\mathrm{A}_0 - k_2\mathrm{B}_0}{k_1+k_2} e^{-(k_1+k_2)t} + \frac{k_2}{k_1+k_2}(\mathrm{A}_0 + \mathrm{B}_0)$

(e) [Hint to students: *you do not need to solve a DE to get the answer below*.]

$[\mathrm{B}](t) = \frac{k_2 B_0 - k_1\mathrm{A}_0}{k_1+k_2} e^{-(k_1+k_2)t} + \frac{k_1}{k_1+k_2}(\mathrm{A}_0 + \mathrm{B}_0)$

Part 3 (b): $\overline{a} = \frac{k_2}{k_1+k_2}(\mathrm{A}_0 + \mathrm{B}_0)$, $\overline{\mathrm{b}} = \frac{k_1}{k_1+k_2}(\mathrm{A}_0 + \mathrm{B}_0)$

(e) Hint: at equilibrium [A] and [B] are not changing.

5. Suggested goals for Tuesday's lab and Wednesday's class.

(a) In lab students should work through all of parts (1) & (2), assuming that you put the answers on the board, give them suggestions on the notation, and help them through the algebra. A few of the best and fastest students may get part (3) started.

(b) In class on Wednesday teachers should have the students sit with their lab groups. The teacher should quickly review the process we used to solve the DEs in parts (1) and (2) of the lab, and then help the students work through part 3. [Note that if students have put their solutions in the recommended format, then step 3(b) will have been done in step 3(a).] When students get to part (f), you can give them a copy of the computer generated graphs if you would like to do so.

6. A lab quiz works well as a means for checking to see if students have learned this lab. The lab following fall break is short and easy, so there is time during that lab period to give a quiz. And, after all, we will have given them all the answers, so we need to test them to see if they've understood the ideas and techniques in this lab.