Key for Kinetics of the Hydrolysis of Urea

The data file "Hydrolysis of Urea," which is in your group's Dropbox folder, contains data collected during the hydrolysis of urea

$$CO(NH_2)_2(aq) + H_2O(l) \rightarrow 2NH_3(aq) + CO_2(g)$$

displayed as the [urea] as a function of time. The reaction's rate, R, is defined as the change in the concentration of urea per unit change in time is

$$R = \frac{\Delta[\text{urea}]}{\Delta t} = \frac{d[\text{urea}]}{dt}$$

Note that you can move a cursor, which displays three values—the [urea], the time, and the slope—and that you can interpolate between data points. Use this data to answer the following questions.

1. What is the average rate between $t = 4$ days and $t = 16$ days?

To find the average rate we measure the concentration of urea at $t = 4$ days and $t = 16$ and solve; thus

$$R = \frac{0.231 - 0.641}{16.0 - 4.0} = -0.0341 \text{ M/d}$$

2. What is the rate at $t = 10$ days?

Using the cursor function, the slope at $t = 10$ is –0.0341 M/d (or –0.0313 M/d, depending on where you set the cursor).

3. What happens to the reaction's rate over time? Explain your reasoning.

The rate decreases as the reaction proceeds. We know this because the slope of the tangent line, which is $d[\text{urea}]/dt$, decreases with time.

4. At what point in time does the reaction have it's greatest rate?

The reaction's greatest rate is at time $t = 0$; that is, the rate is greatest at the instant the reaction begins.

5. To what value is the rate approaching?

The rate approaches a value of zero, which is the rate when the reaction reaches its equilibrium point.

6. The [urea] as a function of time follows a predictable pattern. Fit an appropriate equation to this data (hint: you have seen similar data in lab) and speculate on the meaning of the equation's variables.

This data should remind you of Newton's law. Fitting the data to the equation

$$[\text{urea}]_t = Ae^{-Ct} + B$$

gives an excellent fit to the data (not shown) with values of 0.900 for A, of -1.17×10^{-18} for B, and of 0.0850 for C. Comparing this equation to Newton's law should convince you that A is the initial concentration of urea, $[\text{urea}]_0$, and that B is the concentration of urea when the reaction reaches equilibrium. In Newton's law, C is a constant that describes the object's inherent ability to radiate heat; here, C is a constant related to the reaction's tendency to occur. We call this the reaction's rate constant, about which we will learn more later.