Kinetics of the Hydrolysis of Urea

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

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

displayed as a plot of [urea] as a function of time. The rate of the reaction is defined as the change in the concentration of urea per unit change in time; that is

$$Rate = \frac{\Delta[\text{urea}]}{\Delta\text{time}} = \frac{d[\text{urea}]}{dt}$$

You will note that there is a cursor which displays values of [urea] and time. In addition, the cursor function displays the slope at each data point. Using this data, answer the following questions.

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

   To find this we measure the [urea] at t = 4 days and 16 days and solve; thus

$$R = \frac{0.231 - 0.641}{16.0 - 3.99} = -0.0341\ \text{M/d}$$

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

   Using the cursor function, the slope at t = 10 days is -0.034 M/d. At what point in time does the reaction have it's greatest rate?

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

   The rate decreases as the reaction proceeds. We can tell this because the slope of the tangent line, which is d[urea]/dt, decreases with time.

4. To what value is the rate approaching?

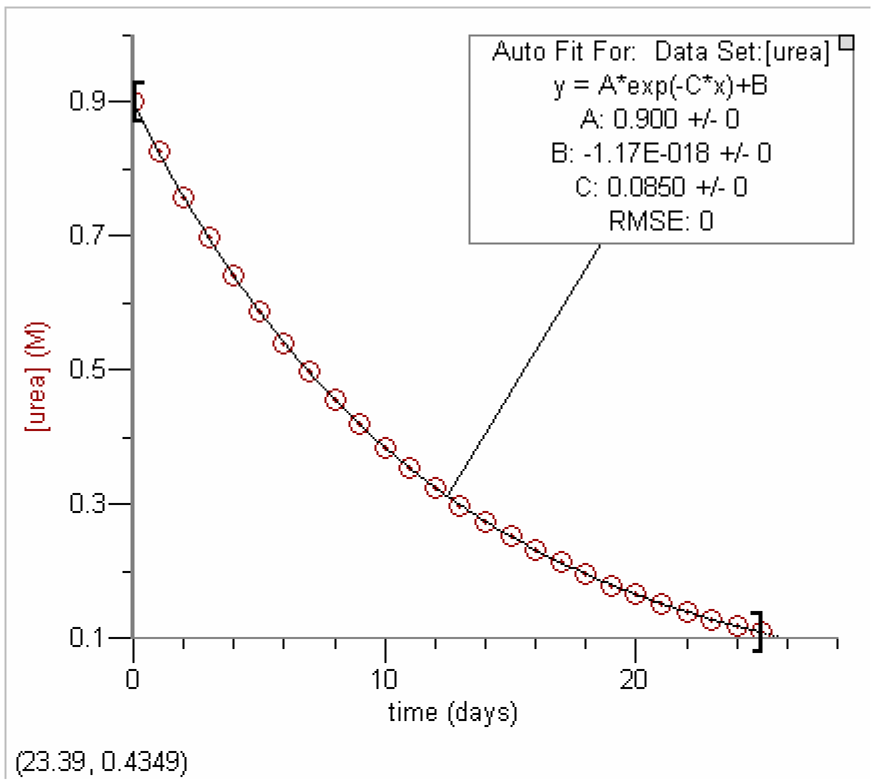
   The reaction's greatest rate is at time t = 0; that is, the rate is greatest at the instant the reaction begins. The rate is approaching a value of zero, which is the rate when the reaction reaches its equilibrium point.

5. The [urea] as a function of time appears to follow a predictable pattern. Fit an appropriate equation to this data (hint: you've 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

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

   gives the result shown here:



   Contrasting this to Newton's law should convince you that A corresponds to the initial concentration of urea, $[urea]_o$, and that B should be the concentration of urea at infinite time, which in this case is zero as the reaction effectively runs to completion. In Newton's law, C is a constant related to the object's inherent ability to radiate heat to the environment; here C is a constant related to the reaction's tendency to occur. We call this constant the reaction's rate constant, about which we will learn more later.