KINETICS

INSTANTANEOUS REACTION RATES

CHEMISTRY 165 // SPRING 2020

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KINDS OF RATES

Exactly how do I measure the rate of the reaction?

Suppose you have the following degradation reaction

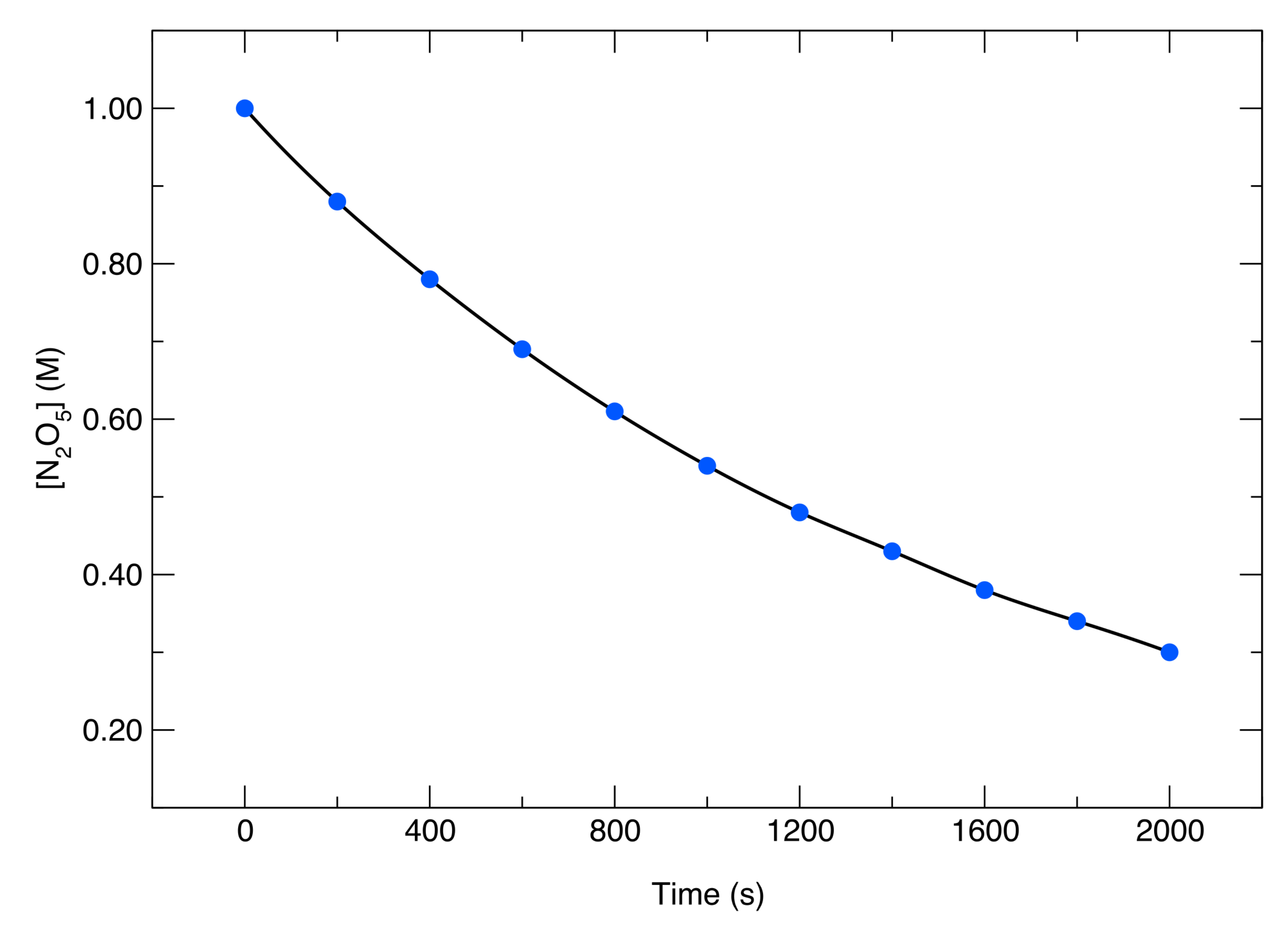
$$2\ N_2O_5\ (aq) \rightarrow NO_2\ (aq) + O_2\ (g)$$

for which you have collected the data shown to the right (the concentration of the reactant plotted as a function of time).

*Assume all times are good to the ones place.

Before we go too much further, make sure you understand the following:

1. Typically, we monitor the reactant because we *know* what it is.
2. The concentration of the reactant should decrease. Conversely, the concentration of the product(s) should increase over time.
3. After a long time, the reactant concentration will plateau rather than go to zero (we will explain this in a later chapter).
4. The rate of change of the reactant concentration is not constant. The rate is greatest in the beginning and decreases with time. Why? For now, let's say that at the beginning we have lots of reactant, so the reaction rate is fast; and toward the end, the reactant concentration is low, so the reaction rate slows down.



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***Q:** After 1000 seconds, what is the reaction rate?*

***A:** It depends! In general, there are two types of rates that can be measured:*

- *The average rate*
- *The instantaneous rate*

Let's look at the differences between the two rates using the plot to the right.

*Assume all times are good to the ones place.

AVERAGE RATE

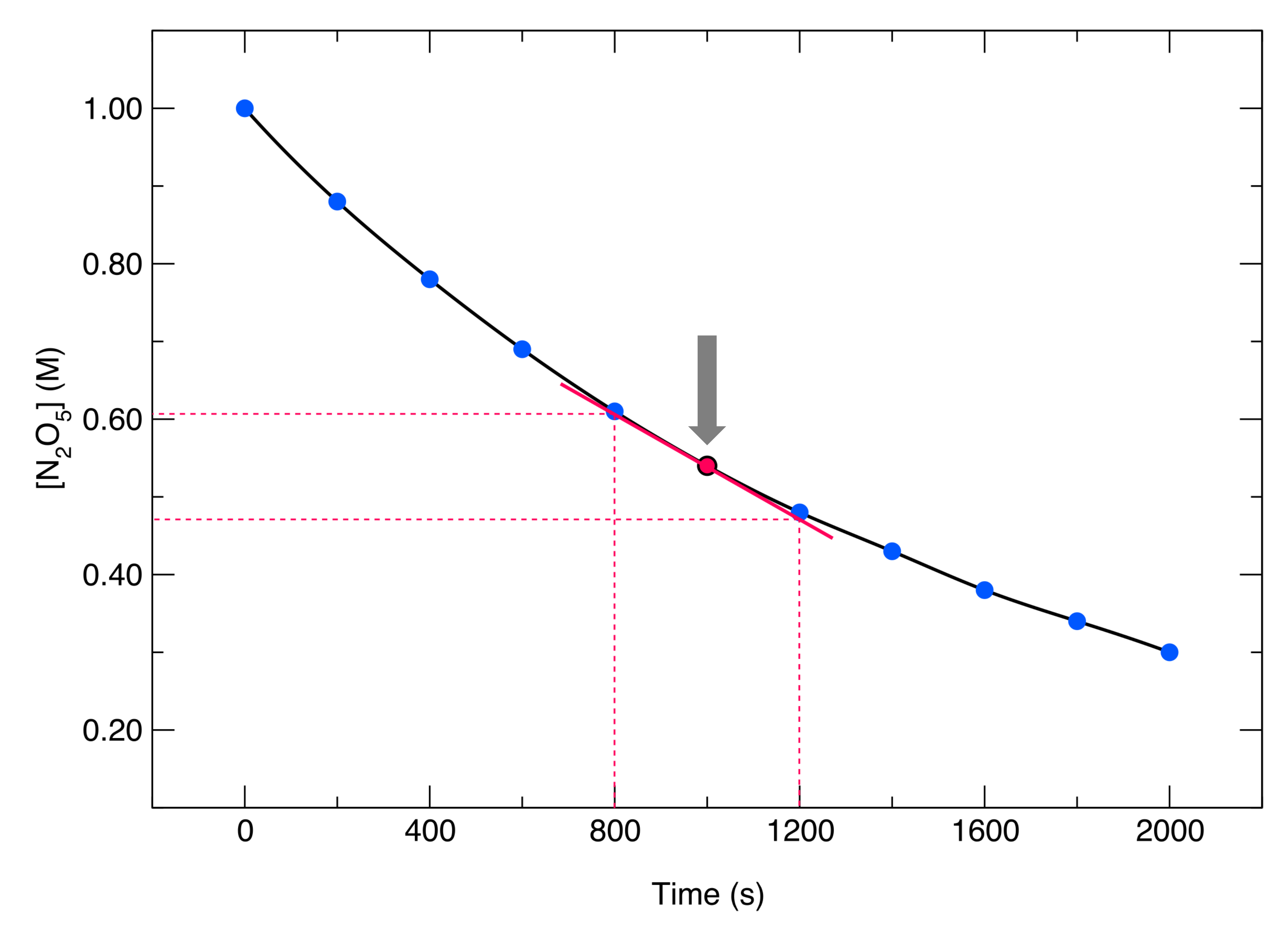
The average rate is the averaged *over* a certain amount of time. In other words, you'll need to consider an actual timeframe. For instance, in the plot below, we can obtain an average rate over 1000 seconds, from 0 to 1000 seconds (red dots).

$$\text{Av. Rate} = -\frac{\Delta[N_2O_5]}{\Delta t} = -\frac{[N_2O_5]_{1000\text{ s}} - [N_2O_5]_{0\text{ s}}}{\Delta t} = -\frac{0.54\text{ M} - 1.00\text{ M}}{1000\text{ s} - 0\text{ s}} = 0.00046\ \frac{\text{M}}{\text{s}}$$

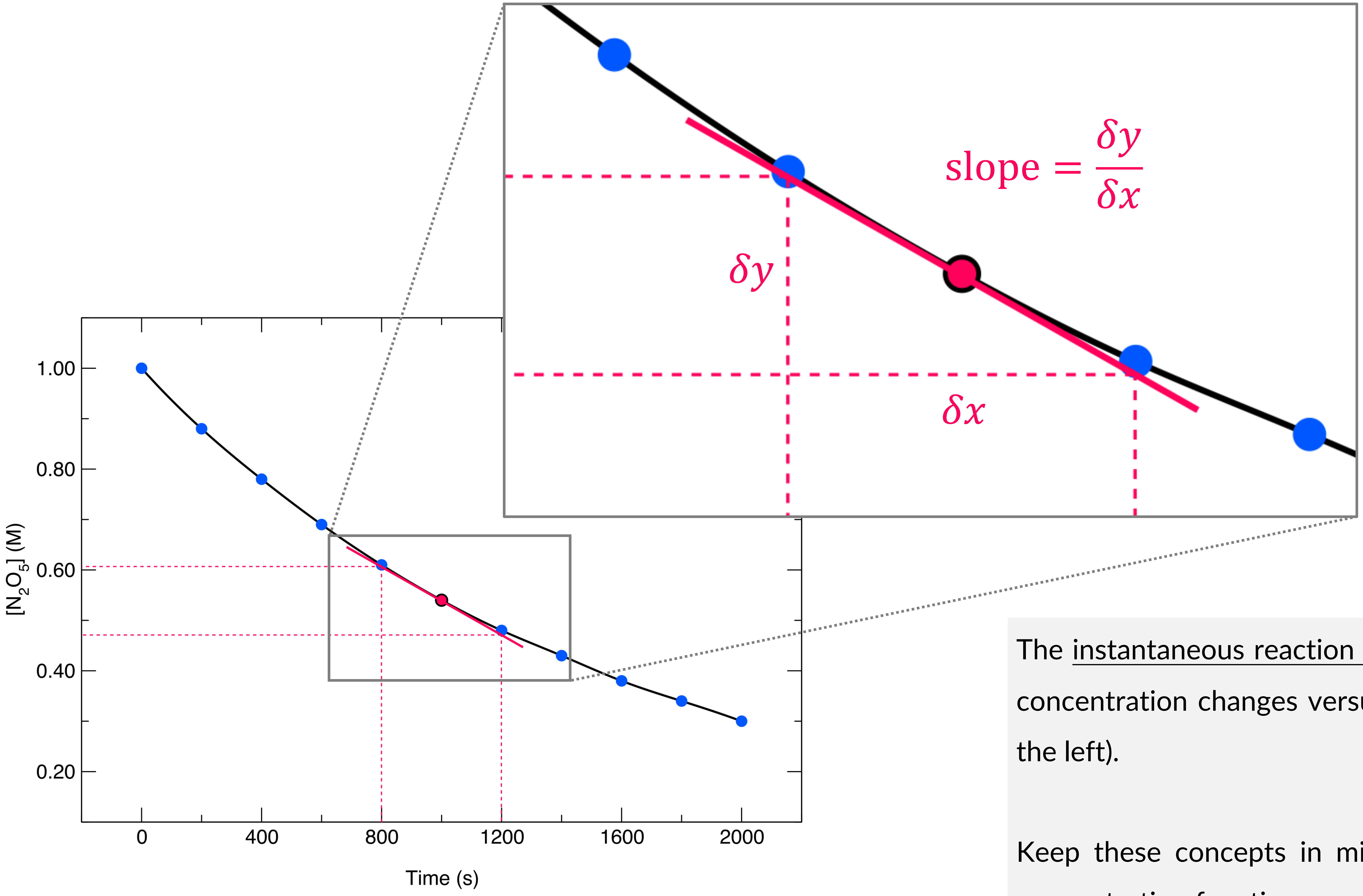
INSTANTANEOUS RATE

More common, however, is the instantaneous rate, which is measured *at* a particular time—at 1000 seconds. In the plot below, we can obtain an instantaneous rate at 1000 seconds by calculating the slope of the concentration curve at that instant.

$$\text{Inst. Rate} = -\frac{\Delta[N_2O_5]}{\Delta t} = \frac{[N_2O_5]_{1200\text{ s}} - [N_2O_5]_{800\text{ s}}}{\Delta t} = -\frac{0.48\text{ M} - 0.61\text{ M}}{1200\text{ s} - 800\text{ s}} = 0.00032\ \frac{\text{M}}{\text{s}}$$



A MATHEMATICAL ASIDE



What slope and what line?

If you have taken calculus or physics, you may be familiar with the term *derivative*, which is a measure of the change in a function's value upon perturbation of the variable. For example, for the function

$$y = f(x) = x^2$$

the derivative of this function tells us how quickly the value of y changes as we change the value of x. The derivative is expressed as

$$f'(x) = \frac{\delta y}{\delta x} = 2x$$

where the δ symbol denotes a change over a *small* increment. The value of the derivative at a particular value of x is equal to the slope of a line tangent to the function at that particular value.

The instantaneous reaction rate is the derivative of some function that tells us how the concentration changes versus time, at a particular instant in time (see plot and inset to the left).

Keep these concepts in mind when we get to the point where we write down the concentration functions.