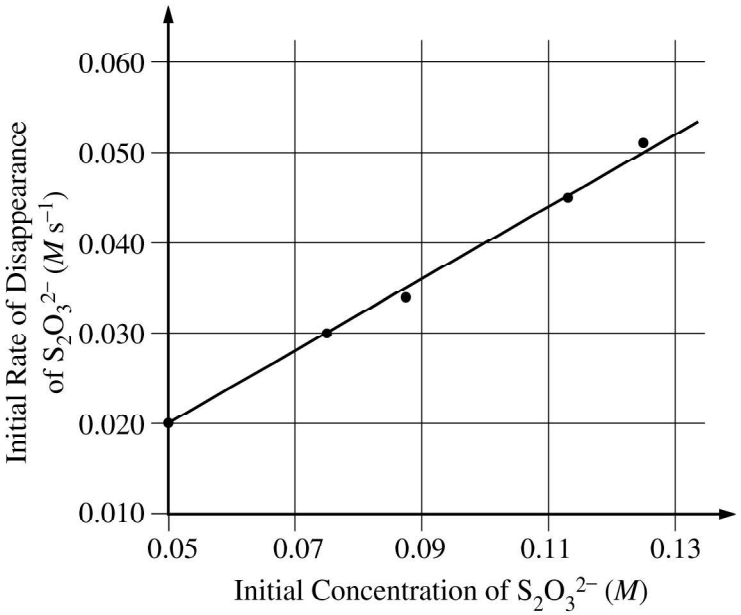
AP® CHEMISTRY
2009 SCORING GUIDELINES (Form B)

Question 2 (8 points)

$$S_2O_3^{2-}(aq) \xrightarrow{H^+} SO_3^{2-}(aq) + S(s)$$

A student performed an experiment to investigate the decomposition of sodium thiosulfate, $Na_2S_2O_3$, in acidic solution, as represented by the equation above. In each trial the student mixed a different concentration of sodium thiosulfate with hydrochloric acid at constant temperature and determined the rate of disappearance of $S_2O_3^{2-}(aq)$. Data from five trials are given below in the table on the left and are plotted in the graph on the right.

Trial	Initial Concentration of $S_2O_3^{2-}$ (aq) (M)	Initial Rate of Disappearance of $S_2O_3^{2-}$ (aq) $(M\ s^{-1})$
1	0.050	0.020
2	0.075	0.030
3	0.088	0.034
4	0.112	0.045
5	0.125	0.051



(a) Identify the independent variable in the experiment.

The initial concentration of $S_2O_3^{2-}(aq)$	One point is earned for the correct answer.

(b) Determine the order of the reaction with respect to $S_2O_3^{2-}$. Justify your answer by using the information above.

Using trials 1 and 2: $\frac{\text{rate}_2}{\text{rate}_1} = \frac{k_2[S_2O_3^{2-}]^{m_2}}{k_1[S_2O_3^{2-}]^{m_1}}$ $\frac{0.030\ M\ s^{-1}}{0.020\ M\ s^{-1}} = \frac{[0.075]^m}{[0.050]^m}$ $1.5 = (1.5)^m$, so $m = 1$ and the reaction is **first order** with respect to $S_2O_3^{2-}$. Note: Other correct justifications are acceptable.	One point is earned for the correct order. One point is earned for a correct justification.

Question 2 (continued)

(c) Determine the value of the rate constant, k, for the reaction. Include units in your answer. Show how you arrived at your answer.

$\text{rate} = k[S_2O_3^{2-}] \Rightarrow k = \dfrac{\text{rate}}{[S_2O_3^{2-}]}$ Using the data from trial 1, $k = \dfrac{0.020\ M\ s^{-1}}{0.050\ M} = \mathbf{0.40\ s^{-1}}$ **OR** the rate constant is equal to the slope of the line $k = \dfrac{(0.052 - 0.020)\,M s^{-1}}{(0.13 - 0.05)\,M} = \dfrac{0.032\,M s^{-1}}{0.08\,M} = \mathbf{0.40\ s^{-1}}$	One point is earned for the correct value. One point is earned for the correct units.

(d) In another trial the student mixed 0.10 M $Na_2S_2O_3$ with hydrochloric acid. Calculate the amount of time it would take for the concentration of $S_2O_3^{2-}$ to drop to 0.020 M.

$\ln[A]_t - \ln[A]_0 = -kt \Rightarrow \ln\dfrac{[A]_t}{[A]_0} = -kt$ $\ln\dfrac{[S_2O_3^{2-}]_t}{[S_2O_3^{2-}]_0} = -kt$ $\ln\dfrac{0.020}{0.10} = (-0.40\ s^{-1})(t) \Rightarrow t = \dfrac{-1.61}{-0.40\ s^{-1}} = \mathbf{4.0\ s}$	One point is earned for the correct setup. One point is earned for the correct answer with units.

(e) On the graph above, sketch the line that shows the results that would be expected if the student repeated the five trials at a temperature lower than that during the first set of trials.

The line drawn should start on the y-axis at a lower point than the line already plotted and should have a less steep slope.	One point is earned for an acceptable line.