

Practice  
#1

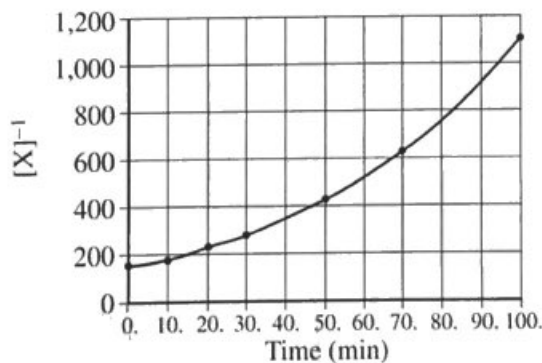
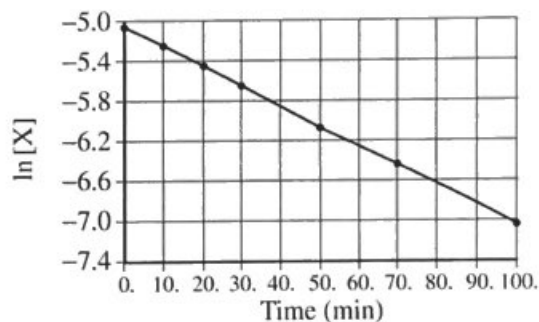
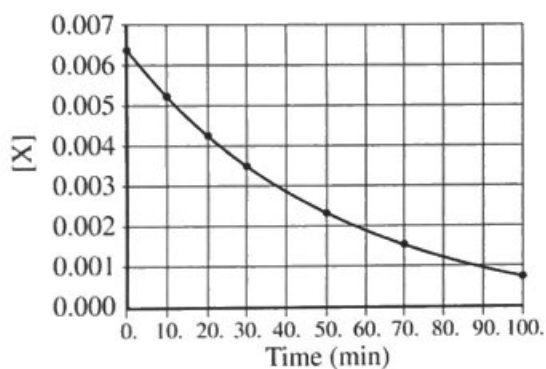
**AP<sup>®</sup> CHEMISTRY**  
**2005 SCORING GUIDELINES (Form B)**

**Question 3**



The decomposition of gas X to produce gases Y and Z is represented by the equation above. In a certain experiment, the reaction took place in a 5.00 L flask at 428 K. Data from this experiment were used to produce the information in the table below, which is plotted in the graphs that follow.

Time (minutes)	[X] (mol L <sup>-1</sup> )	ln [X]	[X] <sup>-1</sup> (L mol <sup>-1</sup> )
0	0.00633	-5.062	158
10.	0.00520	-5.259	192
20.	0.00427	-5.456	234
30.	0.00349	-5.658	287
50.	0.00236	-6.049	424
70.	0.00160	-6.438	625
100.	0.000900	-7.013	1,110



(a) How many moles of X were initially in the flask?

[X] at 0 minutes = 0.00633, so

$$5.00 \text{ L} \times 0.00633 \frac{\text{mol X}}{\text{L}} = 3.17 \times 10^{-2} \text{ mol X}$$

One point is earned for correct number of moles of X.

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Question 3 (continued)

(b) How many molecules of Y were produced in the first 20. minutes of the reaction?

<p>After 20. minutes of reaction, the number of moles of X remaining in the flask is <math>(5.00 \text{ L}) \times (0.00427 \frac{\text{mol X}}{\text{L}}) = 2.14 \times 10^{-2} \text{ mol X}</math>.</p> <p>Then the number of moles of X that reacted in the first 20 minutes is <math>(3.17 \times 10^{-2} \text{ mol X}) - (2.14 \times 10^{-2} \text{ mol X}) = 1.03 \times 10^{-2} \text{ mol X}</math>.</p> <p>Thus the number of molecules of Y produced in the first 20. minutes is</p> $(1.03 \times 10^{-2} \text{ mol X}) \times \left( \frac{2 \text{ mol Y produced}}{1 \text{ mol X reacted}} \right) \times \left( \frac{6.02 \times 10^{23} \text{ molecules Y}}{1 \text{ mol Y}} \right)$ $= 1.24 \times 10^{22} \text{ molecules Y produced}$	<p>One point is earned for the number of moles of X that react or for the correct stoichiometry between X and Y.</p> <p>One point is earned for the number of molecules of Y produced.</p>
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(c) What is the order of this reaction with respect to X? Justify your answer.

<p>The reaction is first order with respect to X because a plot of <math>\ln [X]</math> versus time produces a straight line with a negative slope.</p>	<p>One point is earned for the correct order and an explanation.</p>
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(d) Write the rate law for this reaction.

$\text{rate} = k[X]^1$	<p>One point is earned for the rate law consistent with part (c).</p>
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(e) Calculate the specific rate constant for this reaction. Specify units.

$\ln \frac{[X]_t}{[X]_0} = -kt$ <p>From the first two data points, <math>\ln \left( \frac{0.00520}{0.00633} \right) = -k(10 \text{ min})</math></p> $k = - \left( \frac{\ln 0.821}{10 \text{ min}} \right) = 0.0197 \text{ min}^{-1}$	<p>One point is earned for the magnitude of the rate constant.</p> <p>One point is earned for the units.</p>
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Question 3 (continued)

- (f) Calculate the concentration of X in the flask after a total of 150. minutes of reaction.

$\ln \frac{[X]_t}{[X]_0} = -kt \text{ means the same thing as } \ln [X]_t - \ln [X]_0 = -kt$ $\ln [X]_{150} - \ln (0.00633) = -(0.0197 \text{ min}^{-1})(150 \text{ minutes})$ $\ln [X]_{150} = -(0.0197 \text{ min}^{-1})(150 \text{ minutes}) + \ln (0.00633)$ $\ln [X]_{150} = -(0.0197 \text{ min}^{-1})(150 \text{ minutes}) + (-5.062)$ $\ln [X]_{150} = -2.955 + (-5.062) = -8.017$ $e^{\ln [X]_{150}} = e^{-8.017} = 3.30 \times 10^{-4}$ $[X] \text{ at } 150. \text{ minutes} = 3.30 \times 10^{-4} M$	<p>One point is earned for substituting into the integrated rate law.</p> <p>One point is earned for the correct concentration of X.</p>
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## Kinetics FRQs (#2)

(a) The independent variable is the initial concentration of  $S_2O_3^{2-}$ .

$$(b) \frac{\text{Trial 2}}{\text{Trial 1}} \quad \frac{.030 = \cancel{.075}^x}{.020 = \cancel{.050}^x}$$

$$1.5 = 1.5^x, \therefore x = 1$$

The reaction is first order with respect to  $S_2O_3^{2-}$ .

$$(c) \text{Rate} = k[S_2O_3^{2-}]$$

$$k = \frac{.030 \text{ M s}^{-1}}{.075 \text{ M}} = .40 \text{ s}^{-1}$$

$$(d) \ln[A]_t - \ln[A]_0 = -kt$$

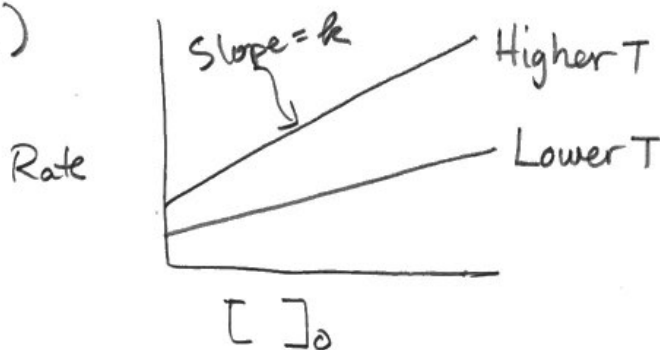
$$\ln \frac{[S_2O_3^{2-}]_t}{[S_2O_3^{2-}]_0} = (-4.0 \text{ s}^{-1})(t)$$

$$\ln \frac{.020}{.10} = (-4.0 \text{ s}^{-1})(t)$$

$$-1.61 = (-4.0 \text{ s}^{-1})t$$

$$t = 4.0 \text{ s}$$

(e)



# Kinetics FRQs #3

$$(a) \Delta H_r^\circ = [0 + 33] - [143 + 90] \\ = -200 \text{ kJ}$$

(b)  $\Delta S^\circ$  for this reaction will be zero (or at least negligible) because the # of moles of gas remains constant.

$$(c) \Delta G = \Delta H - T\Delta S \\ = (-) - 0 \\ = (-)$$

$$(d) \text{Rate} = k [\text{O}_3]^x [\text{NO}]^y$$

- when  $[\text{O}_3]$  doubles &  $[\text{NO}]$  is constant  $\rightarrow$  Rate doubles  
 $\text{O}_3$  is 1<sup>st</sup> order
- when  $[\text{NO}]$  doubles &  $[\text{O}_3]$  is constant  $\rightarrow$  Rate doubles  
 $\text{NO}$  is 1<sup>st</sup> order

$$* \text{Rate} = k [\text{O}_3] [\text{NO}]$$

(e) Overall rate law (determined by Method of Initial Rates) and rate law of rate-determining step (slow step) must be same

Rate Determining Step

- $\rightarrow$  Step 1: Rate =  $k [\text{O}_3] [\text{NO}]$
- $\times$  Step 2: Rate =  $k [\text{O}] [\text{O}_3]$
- $\times$  Step 3: Rate =  $k [\text{NO}_3] [\text{NO}]$

4

2004

(a)  $A = abc$

$$C = \frac{A}{ab} = \frac{.600}{(5.00 \times 10^3 \text{ cm}^{-1} \text{ M}^{-1})(1.00 \text{ cm})}$$

$$C = 1.20 \times 10^{-4} \text{ M}$$

(b)  $\ln [X]_t - \ln [X]_0 = -kt$

$$\ln(4.00 \times 10^{-5}) - \ln(1.20 \times 10^{-4}) = -k(35.0 \text{ min})$$

$$-1.10 = -k(35.0 \text{ min})$$

$$k = 3.14 \times 10^{-2} \text{ min}^{-1}$$

(c)  $\ln [X]_t - \ln [X]_0 = -kt$

$$\ln(1.50 \times 10^{-5}) - \ln(1.20 \times 10^{-4}) = (-3.14 \times 10^{-2} \text{ min}^{-1})(t)$$

$$-2.08 = (-3.14 \times 10^{-2} \text{ min}^{-1})(t)$$

$$t = 66.2 \text{ min}$$

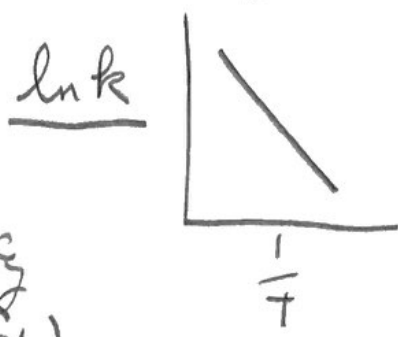
(d)  $\ln [X]_t - \ln [X]_0 = -kt$

$$\ln(6 \times 10^{-4}) - \ln(1.2 \times 10^{-4}) = -3.14 \times 10^{-2} \text{ min}^{-1} t$$

$$-0.693 = -3.14 \times 10^{-2} \text{ min}^{-1} t$$

$$t = 22.1 \text{ min}$$

(e) (i)  $\ln k = \underbrace{-\frac{E_a}{R}}_{\text{slope}} \left( \underbrace{\frac{1}{T}}_x \right) + \underbrace{\ln A}_{\text{frequency factor}}$

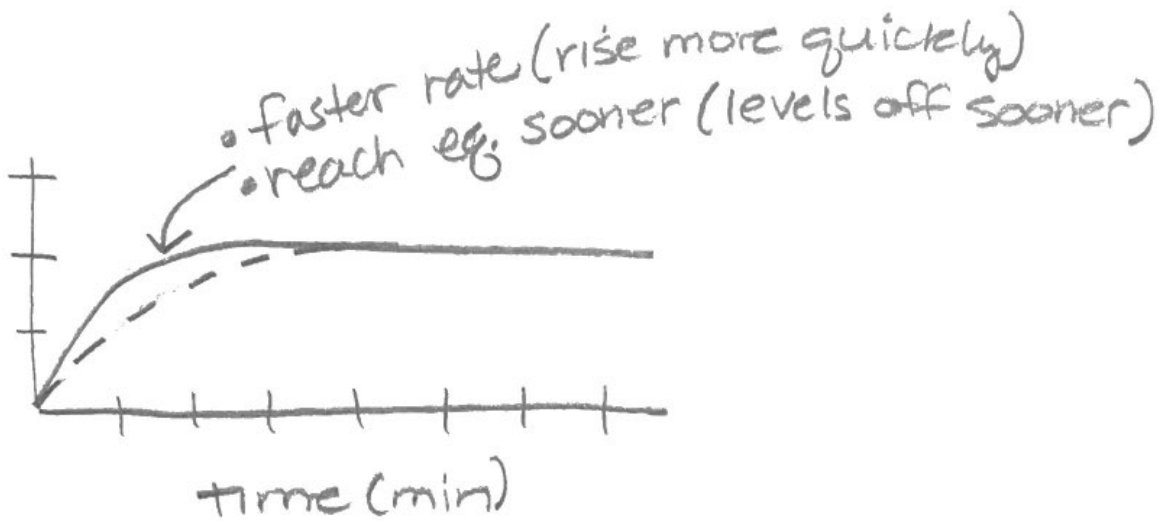


(ii)  $E_a = (\text{slope})(-8.31 \text{ J mol}^{-1} \text{ K}^{-1})$



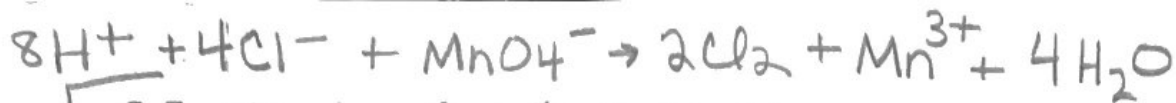
(e)

$[I_3^-]$





6  
2010



25.00 mL of .250 M NaCl  
22°C, P of Cl<sub>2</sub> = .950 atm

(a) (i)

$$\frac{25.00 \text{ mL} \cdot .250 \text{ mol NaCl}}{1000 \text{ mL}} = 6.25 \times 10^{-3} \text{ mol NaCl}$$

$$6.25 \times 10^{-3} \text{ mol Cl}^-$$

(ii)

$$T = 22 + 273 = 295 \text{ K}$$

$$P = .950 \text{ atm}$$

n = ?

$$\frac{6.25 \times 10^{-3} \text{ mol Cl}^- \cdot 2 \text{ mol Cl}_2}{4 \text{ mol Cl}^-} = 3.125 \times 10^{-3} \text{ mol Cl}_2$$

$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{(3.125 \times 10^{-3} \text{ mol Cl}_2)(.0821 \frac{\text{Latm}}{\text{molK}})(295 \text{ K})}{.950 \text{ atm}}$$

$$V = .0797 \text{ L Cl}_2$$

(b) (i) Cl<sup>-</sup>

$$\frac{2.03 \times 10^{-7}}{2.25 \times 10^{-8}} = \frac{[.0312]^x [0.00400]^y [3.00]^z}{[.0104]^x [0.00400]^y [3.00]^z}$$

$$9.02 = 3^x, x = 2$$

\* ORDER OF RXN IS 2 WITH RESPECT TO Cl<sup>-</sup>

(ii) MnO<sub>4</sub><sup>-</sup>

$$\frac{2.03 \times 10^{-7}}{1.02 \times 10^{-7}} = \frac{[.0312]^2 [0.00400]^y [3.00]^z}{[.0312]^2 [0.00200]^y [3.00]^z}$$

$$2 = 2^y, y = 1$$

\* REACTION IS 1<sup>ST</sup> ORDER WITH RESPECT TO MnO<sub>4</sub><sup>-</sup>

(c) (i)

$$\text{Rate} = k [\text{Cl}^-]^2 [\text{MnO}_4^-] [\text{H}^+]^3$$

(6<sup>th</sup> order overall)

$$(ii) \quad 2.25 \times 10^{-8} \text{ M s}^{-1} = k (.014 \text{ M})^2 (.00400 \text{ M}) (3.00 \text{ M})^3$$

$$k = \frac{2.25 \times 10^{-8} \text{ M s}^{-1}}{2.12 \times 10^{-5} \text{ M}^5} = .00106 \text{ M}^{-5} \text{ s}^{-1}$$

(d) It is not likely that the reaction occurs in a single step because the reaction requires the collision of many (13) reactant particles and the frequency of a 13-particle collision is negligible.

or

It is not likely that the reaction occurs in a single step because the orders of the reaction with respect to the reactants do not correspond to the coefficients in the balanced equation.

(the rate law that you write based on the molecularity must match the experimental rate law.)