AP® Chemistry
2004 Sample Student Responses
Form B

3A,

$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

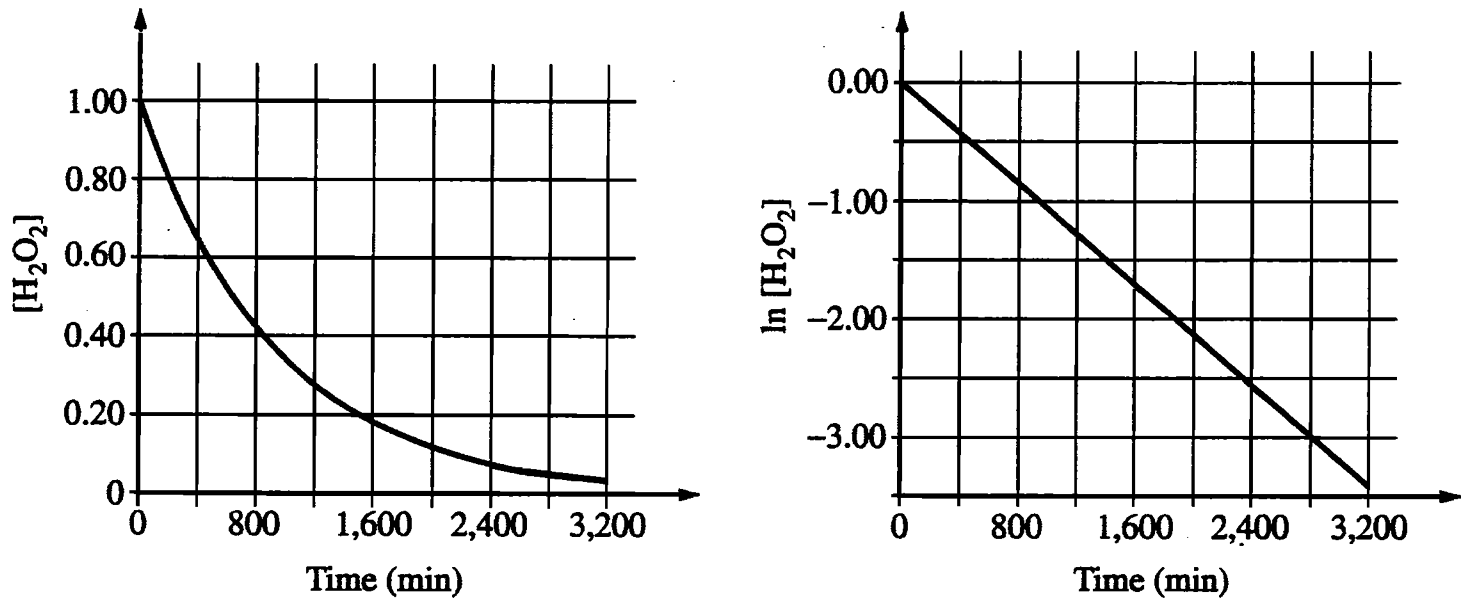
3. Hydrogen peroxide decomposes according to the equation above.

(a) An aqueous solution of H_2O_2 that is 6.00 percent H_2O_2 by mass has a density of 1.03 g mL^{-1}. Calculate each of the following.

(i) The original number of moles of H_2O_2 in a 125 mL sample of the 6.00 percent H_2O_2 solution

(ii) The number of moles of $O_2(g)$ that are produced when all of the H_2O_2 in the 125 mL sample decomposes

(b) The graphs below show results from a study of the decomposition of H_2O_2.



(i) Write the rate law for the reaction. Justify your answer.

(ii) Determine the half-life of the reaction.

(iii) Calculate the value of the rate constant, k. Include appropriate units in your answer.

(iv) Determine $[H_2O_2]$ after 2,000 minutes elapse from the time the reaction began.

a) i) $(125\,mL)\left(\frac{1.03\,g}{1\,mL}\right)\left(\frac{6.00}{100}\right)\left(\frac{1\,mol\,H_2O_2}{34.0158\,g}\right) = \boxed{0.227\ mol\ H_2O_2}$

ii) $(0.227\,mol\,H_2O_2)\left(\frac{1\,mol\,O_2}{2\,mol\,H_2O_2}\right) = \boxed{0.114\ mol\ O_2}$

b) i) rate = $k[H_2O_2]$

Since the plot of the graph of $\ln[H_2O_2]$ vs. time produces a straight line, the reaction is a first-rate reaction

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ii) $t_{1/2} = 600 \text{ min}$

iii) $t_{1/2} = \frac{0.693}{k}$

$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{600} = \boxed{0.00116 \text{ min}^{-1}}$

iv) $\ln[H_2O_2] = -kt + \ln[H_2O_2]_0$

$\ln[H_2O_2] = (-0.00116 \text{ min}^{-1})(2000 \text{min}) + \ln(1.00 \text{ M})$

$\ln[H_2O_2] = -2.31$

$[H_2O_2] = \boxed{0.0993 \text{ M}}$

STOP

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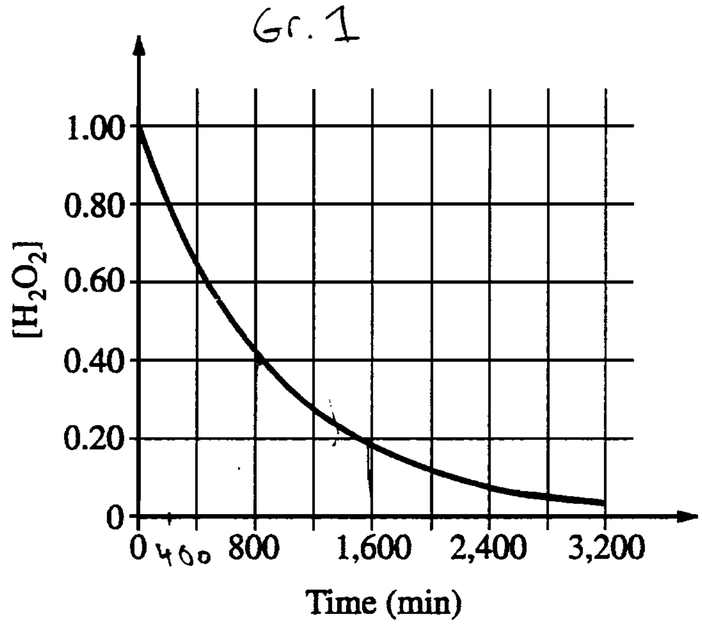

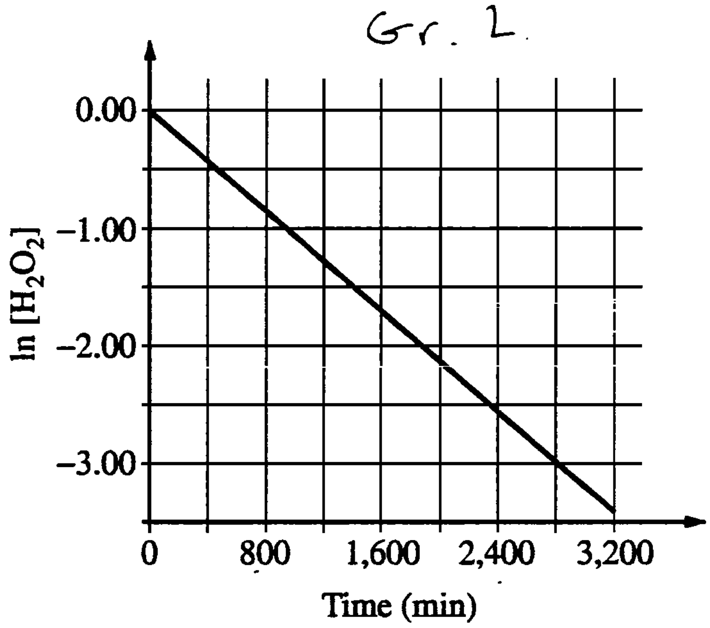

   (i) Write the rate law for the reaction. Justify your answer.

   (ii) Determine the half-life of the reaction.

   (iii) Calculate the value of the rate constant, k. Include appropriate units in your answer. $\rho = \frac{m}{V}$.

   (iv) Determine $[H_2O_2]$ after 2,000 minutes elapse from the time the reaction began.

a) % by mass H_2O_2 = $\frac{m_{H_2O_2} \times 100}{m_{soln}}$ = 6% $\qquad \rho_{H_2O_2} = 1.03\ g/mL$

(i) n = ? $\quad$ V = 125 mL $\Rightarrow m_{soln} = \rho \cdot V = \frac{1.03\,g}{mL} \times 125\,mL = 128.75\,g$

$n = \frac{m}{M}$ $\qquad M_{H_2O_2} = 2(1.0079) + 2(16) = 34.0158\ g/mol$

$m_{H_2O_2} = \frac{\%\ mass\ of\ H_2O_2 \times mass\ of\ soln}{100} = \frac{6 \times 128.75}{100} = 7.725\,g$

$n_{H_2O_2} = \frac{m}{M} = \frac{7.725}{34.0158} = 0.22710 = 0.227$ moles

(ii) Reacting ratio: $\underset{2}{2H_2O_2} \rightarrow \underset{1}{1O_2}$

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3B2

2 1

0.227 x ⇒ $x = \frac{0.22710}{2} = 0.11355 = \boxed{0.114}$ moles

b)(i) It is of the 1st order

$\ln[H_2O_2] = \ln[H_2O_{2\,initially}] - kt$

In Gr 1 ⇒ exponential graph with $t_{1/2}$ =

In Gr 2 ⇒ a straight line with -ve slope for the plot of $\ln[H_2O_2]$ vs time

ii) $t_{1/2} = \frac{\ln 2}{K}$ K = slope of Gr 2 $= \frac{rise}{run} = \frac{0-(-3)}{2800}$

$= \frac{\ln 2}{3/2800}$ $= \frac{3}{2800} = 1.07 \times 10^{-3}$

$= 646.937 = \boxed{647 \text{ minutes}}$

(iii) K = slope of graph 2 $= \frac{0-(-3)}{2800} = 1.07 \times 10^{-3}$ M/min.

(iv) $t = 2000$

$\ln[H_2O_2] = [\ln H_2O_2]_{initial} - kt$

$\ln[H_2O_2] = 0 - \frac{3}{2800}(2000)$

$\ln[H_2O_2] = 2.1428$

$e^{\ln H_2O_2} = e^{2.1428}$

$H_2O_2 = 8.5237 = \boxed{8.524 \text{ M}}$

STOP

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$d = \frac{m}{V}$ 3C,

$1.03\frac{g}{ml}$ 125 • .06

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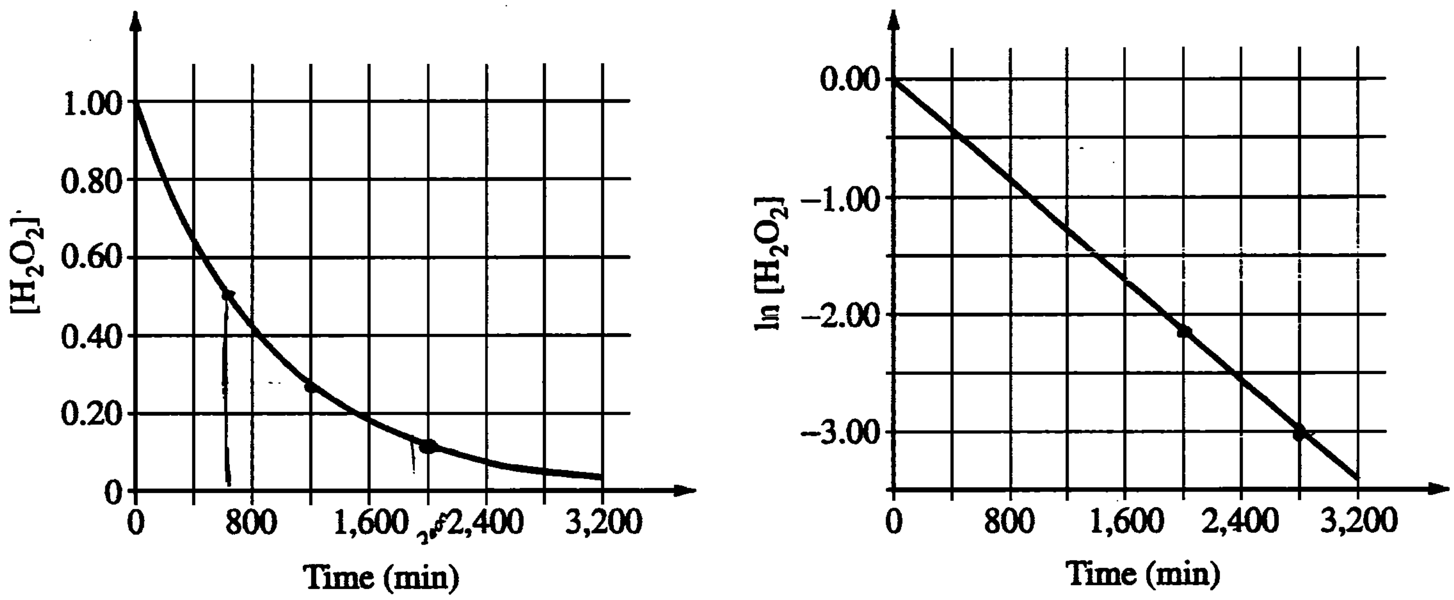

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a). density = $\frac{\text{mass}}{\text{volume}}$ $d = 1.03\frac{g}{ml}$ m = x V = x

~~H_2O_2 = 125.0~~ $1.03\frac{g}{ml} = \frac{x \text{ grams } H_2O_2}{125 \cdot .06}$

7.725 g H_2O_2

$\frac{7.725\,g}{34\,\frac{mol}{g}}$ = **.227 mol H_2O_2**

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3C2

ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

ii

Since .227 mol H_2O_2 decomposes and ratio to O_2 is 2:1, $\frac{1}{2}$ of moles of H_2O_2 = mol O_2

$\frac{.227 \text{mol}}{2}$ = .114 mol O_2 produced

b. i For every 600 minutes the H_2O_2 looses half its previous mols.

ii Based on the graphs given the half life appears to be in the vicinity of 600 minutes as it takes that long for $\frac{1}{2}$ of the reactant to dissapear/decompose.

iii $\ln[A]_t - \ln[A]_0 = -kt$

~~ln − ln₀ = −k · 2800~~

ln .05 − ln 1 = −k 2800

iv Based on the graph, the H_2O_2 will be 10.42 at t = 2000.

t = 1800 → H_2O_2 = 12.5 $\frac{2000}{2400}$ = .83

.83 · 12.5 = 10.41$\overline{6}$

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