

KINETICS OF CONTACT LENS CLEANING

LAB KIN.2

PURPOSE

Determine the time required to safely clean a pair of contact lens using Platinum catalyzed decomposition of Hydrogen Peroxide.

CHEMICALS

Solution of Hydrogen Peroxide

CIBA platinum-coated disc

Buffer solution ($\text{NaH}_2\text{PO}_4 \leftrightarrow \text{Na}_2\text{HPO}_4$) pH=7

DI water

EQUIPMENT

Erlenmeyer flasks 125 ml

Stoppers

Hot plate and 400 ml beaker

Graduated cylinders 50-100 mL or pipettes 5 -10 mL

Magnetic stirrer

Laptop with Logger Pro 3.3

Thermometer or Temperature Probe

Barometer

Vernier pressure sensor

Asosep Contact Lens Cleaning Apparatus

SAFETY CONCERNS AND WASTE DISPOSAL

Safety goggles should be worn, as 3% Hydrogen peroxide solution will irritate eyes. If contact with eye occurs, flush eyes with copious amounts of water or saline solution. All reaction materials, except the disc, may be disposed of in the laboratory sink. Dry the disc after use and return it to you instructor.

PRE LAB ASSIGNMENT

Prelab Assignment

1. A 3.0 % solution of hydrogen peroxide is 3.0 grams of hydrogen peroxide per 100 mL of solution. Convert this concentration from mass-to-volume percent to molarity.
2. A 60 ppm solution of hydrogen peroxide is 60 grams of hydrogen peroxide per 1 million grams of solution. Assume the density of the solution is 1.00 g/mL and convert this concentration from ppm to molarity.
3. In this experiment you will be using the following dilution scheme.

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	Volume of H ₂ O ₂ /mL	Volume of DI water/mL	Volume of Buffer solution/mL
Trial 1 (90%)	45	0	5
Trial 2 (75%)	37.5	7.5	5
Trial 3 (50%)	25	20	5
Trial 4 (25%)	12.5	32.5	5

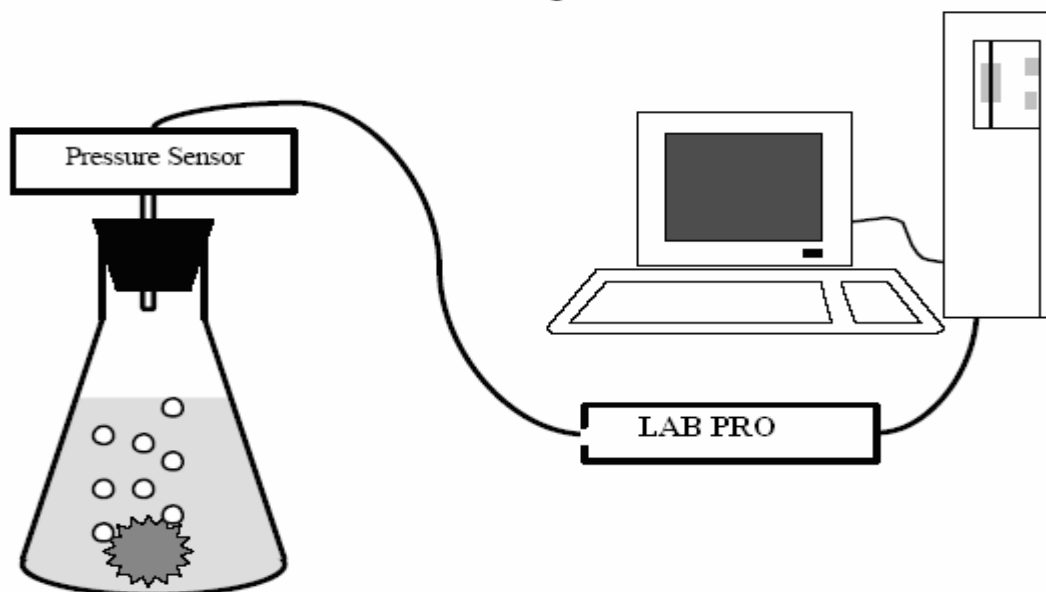
Determine the molarity of hydrogen peroxide for each trial, assuming the stock hydrogen peroxide is a 3.0 mass-to-volume percent solution.

MEASUREMENT OF THE PRESSURE OF OXYGEN EVOLVED UNDER CONDITIONS OF CONSTANT VOLUME

This method acquires the pressure of the oxygen evolved with a pressure sensor attached to a personal computer. The low-pressure sensor used in this experiment measures the difference between the pressure within the flask and the pressure of the lab. The partial pressure of the air and partial pressure of the water vapor within the flask are unchanged by the reaction and are assumed to equal to the pressure within the room. The sensor then measures the partial pressure of the oxygen generated by the reaction.

Prepare the solution to be studied and allow the solution to equilibrate with a constant temperature bath, if one is being used. Once the solution has reached a constant temperature and the AODisc® is prepared, place the disc in the solution, quickly stopper the flask and have the computer start to record data. Gently and consistently swirl the flask and collect pressure versus time until the partial pressure of oxygen has increased to about 8 kPa. The instructor will assist you in setting up the data acquisition system.

Figure 5



It is necessary to know the temperature of the flask and the volume in which the gas is contained to convert the partial pressure of the generated oxygen to moles of generated oxygen. The volume of the gas is not simply the volume of the flask, because some of the flask's volume is occupied by the liquid solution. The volume of gas is calculated by subtracting the volume of the reaction solution from the volume of the stoppered flask. The volume of the stoppered flask is calculated from the mass of the water required to fill the flask and stopper and the density of water. The volume of 125mL flask and tubing of pressure sensor is 147 mL.

PROCEDURE- METHOD OF INITIAL RATES

1. Prepare two samples of each of the four solutions in 125 mL Erlenmeyer flasks as is shown in the table below. The buffer is used to make sure that these solutions are at the same pH and that the pH of the reactant mixture remains relatively constant during the reaction. Care should be taken to ensure that each of these solutions is at the same temperature. The volume of 125 mL flask & tubing of pressure sensor is 147 mL.

During the first few minutes after placing a dry platinum-coated disc into the hydrogen peroxide solution, the rate of the decomposition of hydrogen peroxide actually increases. Eventually the rate of the reaction stabilizes, as the disc seems to become accustomed to the solution. The second identical solution for each trial is prepared to activate the platinum-coated disc in a solution that will not dilute the solution into which the disc is placed during the experiment.

	Volume of H ₂ O ₂ /mL	Volume of DI water/mL	Volume of Buffer solution/mL
Trial 1 (90%)	45	0	5
Trial 2 (75%)	37.5	7.5	5
Trial 3 (50%)	25	20	5
Trial 4 (25%)	12.5	32.5	5

2. Before acquiring data, activate the platinum-coated disc for at least 30 minutes by placing the disc in one of the two samples of the trial 1 buffered hydrogen peroxide solution.

3. Record the atmospheric pressure in the room from a barometer or from the instructor. Measure the temperature of the second trial 1 solution.

4. Once the disc is prepared, place it into the second trial 1 hydrogen peroxide solution, stopper the flask and begin to record the pressure of oxygen generated while gently and consistently swirling the flask.

5. Click on “collect” on Logger Pro, after at least 300 seconds click “stop” on the Logger Pro.

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Place the platinum disc in one of the trial 2 solutions for at least 5 minutes to maintain the activation of the disc. Measure the temperature of the second trial 2 solution. Place the disc into the second trial 2 solution and measure the amount of generated oxygen as before. Repeat this procedure for trials 3 and 4. Do not discard the trial 3 solution that was used to activate the disc and when finished with trial 4 place the disc into this solution. It may be necessary to shake or stir the solution while collecting data.

TEMPERATURE DEPENDENCE OF REACTION RATE-PROCEDURE

Prepare four replicates of the following solution in 125 mL or 25mL Erlenmeyer flasks. The disc should remain in the trial 3 activation solution from above while the solutions are being prepared and for at least five minutes between the trials.

	Volume of H ₂ O ₂ /mL	Volume of DI water/mL	Volume of Buffer solution/mL
(50%)	25	20	5

Prepare four temperature baths with temperatures that differ by about 8 to 10°C, e.g. 12, 20, 28 and 36°C. For each trial allow the hydrogen peroxide solution inside the Erlenmeyer flask to equilibrate to within a degree of the temperature in the bath and record the temperature of the solution. Record the atmospheric pressure in the room from a barometer or from the instructor. Place the disc into the hydrogen peroxide solution, stopper the flask and begin to record the pressure of oxygen generated while gently and consistently swirling the flask in the constant temperature bath. Repeat these measurements for each of the solution temperatures.

DATA HANDLING

Method of Initial Rates

Using this conversion factor on the rate with units of mL*s⁻¹ will give a new rate with units of mol of oxygen generated per second, mol*s⁻¹. This rate can be related to the rate of hydrogen peroxide decomposed by using the stoichiometry of the reaction. Finally, to get the rate with units of M*s⁻¹ it is necessary to divide the rate with units of moles of hydrogen peroxide decomposed per second by the volume of the solution in liters.

- Conversion of rate with units of kPa*s⁻¹ to rate with units of M*s⁻¹.
We first need to convert the pressure of oxygen in kPa to moles of oxygen

$$n = p * \left(\frac{V}{101.325 \text{ kPa} / \text{atm} * R * T} \right) \quad (1)$$

where:

- p is the pressure of the oxygen in kPa,
- V is the volume of the gas in L, obtained by subtracting the volume of the solution from the volume of flask.

- T is the temperature of the water in the flask in Kelvin
- and R is the ideal gas law constant with units of L*atm*mol⁻¹*K⁻¹.
 $R = 0.082056 \text{ L*atm*mol}^{-1}\text{K}^{-1}$

Using this conversion factor on the rate with units of kPa*s⁻¹ will give a new rate with units of mol of oxygen generated per second, mol*s⁻¹. This rate can be related to the rate of hydrogen peroxide decomposed by using the stoichiometry of the reaction, see equation 2. Finally, to get the rate with units of M*s⁻¹ it is necessary to divide the rate with units of moles of hydrogen peroxide decomposed per second by the volume of the solution in liters.

$$\text{rate} = -\frac{1}{2} \frac{\Delta[H_2O_2]}{\Delta t} = \frac{\Delta O_2}{\Delta t} \quad (2)$$

Once the initial rate of the reaction and the concentration of hydrogen peroxide are in the desired units, it is possible to obtain the order of the reaction with respect to hydrogen peroxide, a, and value of the rate constant, k.

The order of the reaction is determined by plotting the natural log of the rate versus the natural log of the hydrogen peroxide. This plot should be linear and the slope of the line that fits the data estimates the order of the reaction with respect to hydrogen peroxide, see figure 2 and equation 3. It is customary to round values to the nearest integer.

$$\ln(\text{rate}) = a([\text{H}_2\text{O}_2]) + \ln(K) \quad (3)$$

Knowledge of the reaction order allows the rate constant (K) to be calculated for every run by taking the initial rate of the reaction in units of M*s⁻¹ divided by the initial molarity of hydrogen peroxide raised to the order of the reaction, see equation 4.

$$K = \frac{\text{rate}_o}{[\text{H}_2\text{O}]^a} \quad (4)$$

Temperature Dependence of Reaction Rate

As above, prepare a plot of either the volume or the pressure of oxygen generated versus time. Transform the initial rate obtained from the slope of the plot to a rate with units of M*s⁻¹ and calculate the rate constant as shown above.

The energy of activation is determined by creating an Arrhenius plot, which is the natural log of the rate constant versus the reciprocal of temperature in Kelvin, see equation 8 and figure 2. The slope of the line that fits this data multiplied by negative R is equal to the energy of activation of the reaction.

Determination of Safe Reaction Time

Use the appropriate integrated rate law and the rate constant determined in the experiment to calculate the amount of time required for a 3.0% solution of hydrogen peroxide to reach a concentration of 60 ppm at a typical room temperature of 25° C.

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Determine the time required in a house where the temperature is 18° C. How do these times compare the recommendation from CIBA Vision of 6 hours?

Table 3: Method of Initial Rates using Low Pressure Sensor

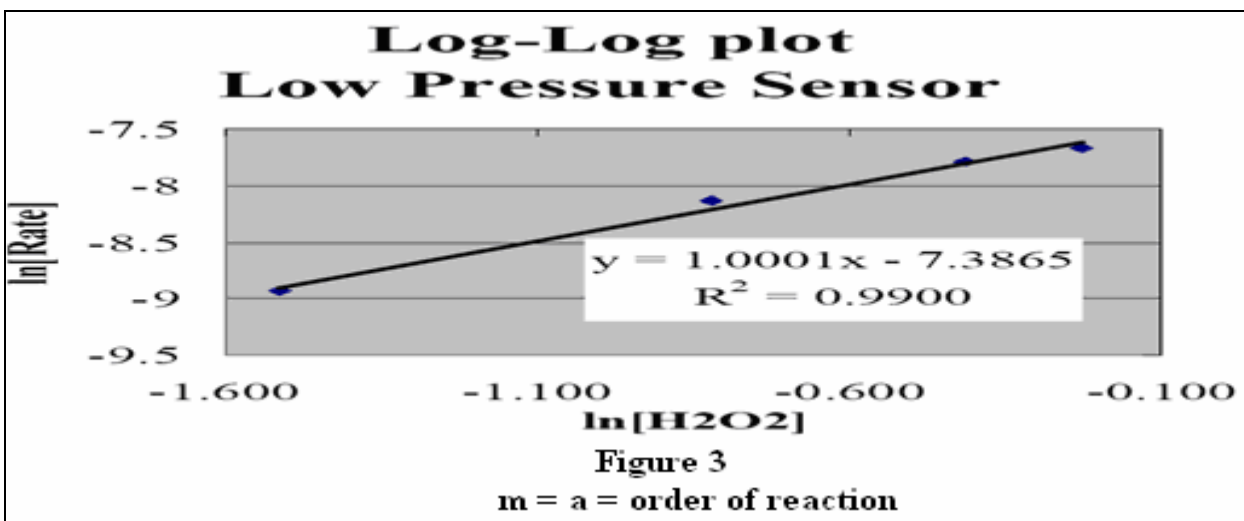
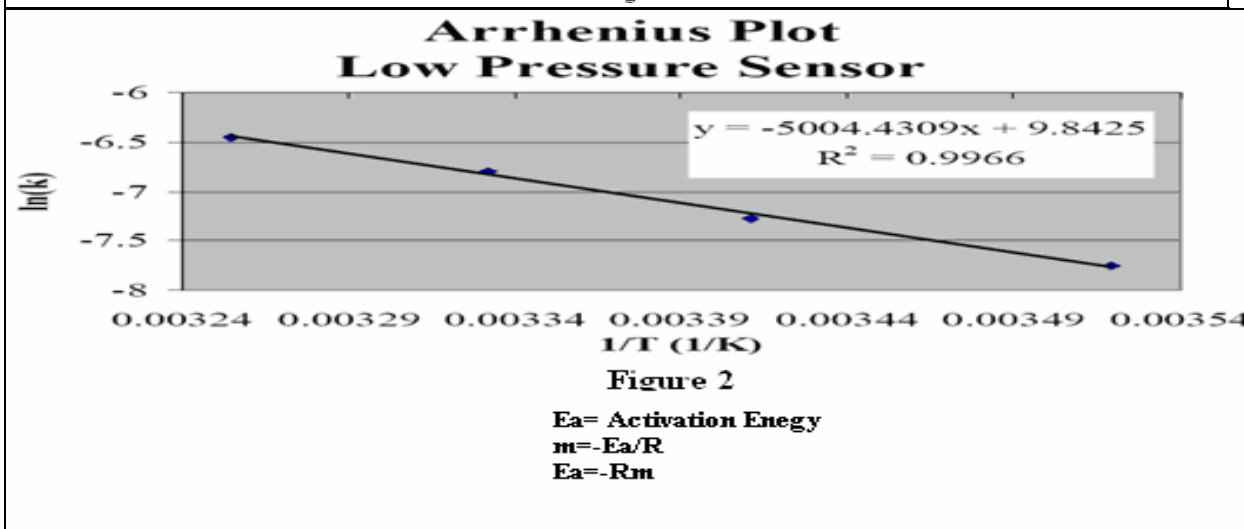
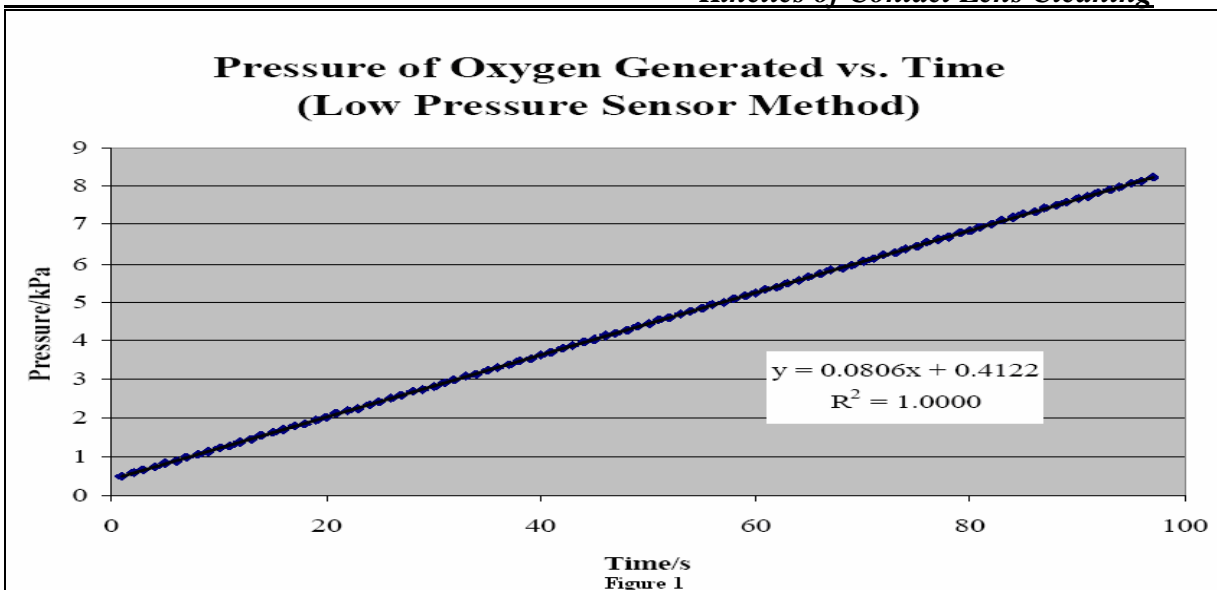
Trial	1	2	3	4
Mass of H₂O in Flask (g)				
Temperature of H₂O (°C)				
Density from CRC(g*mL⁻¹)				
Volume of Flask (mL)	147	147	147	147
Volume of Solution (mL)	50	50	50	50
Volume of Gas (mL)				
Room Pressure (mmHg)				
3% H₂O₂ Dilution factor	.90	.75	.50	.25
[H₂O₂] (M)				
Temperature (C)				
Temperature (K)				
Rate (kPa/s)				
Rate (mol of O₂/s)				
Rate of (mol of H₂O₂/s)				
Rate (M/s)H₂O₂				
Rate Constant, k(s⁻¹) with respect to H₂O₂				
Vapor Pressure of Water @ ambient temp.				

$R=0.0820L \cdot atm/mol \cdot K$

Table 4: Temperature Dependence using Low Pressure Sensor Method*

Trial	1	2	3	4
Mass of H₂O in Flask (g)				
Temperature of H₂O(C)				
Density from CRC(g*mL⁻¹)				
Volume of Flask (mL)				
Volume of Solution (mL)				
Volume of Gas (mL)				
Room Pressure (mmHg)				
3% H₂O₂ Dilution factor				
[H₂O₂](M)				
Temperature (°C)				
Temperature (°K)				
Rate (kPa/s)				
Rate (mol of O₂/s)				
Rate of (mol of H₂O₂/s)				
Rate (M/s)				
Rate Constant, k(s⁻¹) with respect to H₂O₂				

* Using solution from Trial #3 at four different temperatures



Questions

1. Why is the pressure of oxygen generated measured under conditions of constant volume?
2. If the gas collecting apparatus had a slow leak, what effect would this have on the observed rate of reaction?
3. CIBA Vision states that contact lenses that have been soaking in the AOSEPT lens cup for more than 24 hours need to be disinfected again. Speculate as to why this is necessary.
4. What is order of reaction with regard to $[H_2O_2]$?
5. What is rate constant (K) for reaction?
6. What is the energy of activation?
7. How long should contact lenses soak in solution in order for $[H_2O_2]$ to be <60 ppm?