Name: ____________________________________ Date ________________________

Lab Partner __________________________________

FACTORS THAT AFFECT THE RATES OF CHEMICAL REACTIONS

INTRODUCTION

Read and/or review the introductory material for Chapter 13 and the portion of Section 13.5 that deals with collision theory in your textbook.

Collision theory is a theory that can be used to explain why the rate of a chemical reaction is often altered when the reaction conditions are varied. According to collision theory, reactant molecules (or atoms) must collide in order for a chemical reaction to occur. The collisions must occur with sufficient energy and orientation so that the appropriate chemical bonds are broken. The minimum energy that must be supplied in a collision in order for reaction to occur is known as the activation energy, E_a.

The rate or speed by which a chemical reaction occurs can be determined by following how fast the concentration of a reactant decreases or how fast the concentration of a product increases.

For the general reaction of the form: $a\,A + b\,B \rightarrow c\,C + d\,D$ (where A, B, C, and D are gases or substances in solution):

$$\text{rate of formation of C} = \frac{\Delta[C]}{\Delta t} \qquad \text{rate of formation of D} = \frac{\Delta[D]}{\Delta t}$$

$$\text{rate of reaction of A} = -\frac{\Delta[A]}{\Delta t} \qquad \text{rate of reaction of B} = -\frac{\Delta[B]}{\Delta t}$$

Although these rate equations are written in terms of concentrations, any property that is proportional to concentration (for example partial pressure of a gas or the absorption of light by a colored solution) can also be used to study the rate of a chemical reaction.

There are a number of factors that can alter the rate of a chemical reaction. These include:

a) changing the identity of one or more of the reactants (changes the reaction as well as the rate)
b) changing the concentration of one or more of the reactants
c) adding a catalyst or changing the concentration of a catalyst
d) changing the reaction temperature
e) changing the surface area of a solid reactant or catalyst

In this experiment you will study how these factors alter the rate of a chemical reaction.

PROCEDURE

Double click the "Logger Pro" icon and allow the screen to open. Plug the temperature probe into the Go!Link. The Go!Link light should turn green. If not please inform your TA. On three hot plates, set up three water baths in 600 mL beakers for use later on in this experiment. The temperature of one water bath should eventually be about 35^{o}C, another 45^{o}C, and another 55^{o}C. Get together with two other groups on the water baths but not on the experimental portion of the lab. Each group should monitor one of the water baths so that they are all ready to be used when needed. The temperature doesn't need to be exactly these temperatures but should be close. You will use the actual temperature of the water bath when you do that portion of the experiment.

Part A. Identity of a Reactant

Because changing the identity of one or more of the reactants changes the reaction itself, in this part of the experiment you will actually be studying the fact that different substances naturally differ in their reactivity.

Using a well plate, fill up the wells with 3 *M* H_2SO_4, 6 *M* H_3PO_4, 6 *M* $HC_2H_3O_2$, and 6 *M* HCl, respectively. Be sure to keep track of the contents of each well. Sink a small piece (about 1 cm) of magnesium ribbon into the solution in each well.

Observations:

List the acids in order of increasing reactivity with magnesium:

(least reactive acid) __________, __________, __________, __________ (most reactive acid)

Using a well plate, fill three wells with 6 *M* HCl. Sink a small piece (about 1 cm) of magnesium into the solution in the first well, copper into the second, and zinc into the third. Be sure to keep track of the contents of each well.

Observations:

List the metals in order of increasing reactivity with HCl.

(least reactive metal) _____________, _____________, _____________ (most reactive metal)

Part B. Reactant Concentrations

Pipet 1 mL of 6 *M* HCl, 5 *M* HCl, 4 *M* HCl, and 3 *M* HCl into four small, labeled, test tubes (one solution per test tube). Be sure to keep track of the contents of each test tube.

For each test tube (do one test tube at a time):

1. Polish a 1 cm strip of magnesium ribbon with steel wool and determine its mass after polishing.

2. Sink the magnesium ribbon into the solution in the test tube and immediately begin keeping track of the time, in seconds, required for all of the magnesium to react.

3. Record your results in the table below and complete the appropriate row in the table.

	mol HCl	mass of Mg	mol Mg	$\frac{\text{mol HCl}}{\text{mol Mg}}$	time for complete reaction (s)
6 M HCl					
5 M HCl					
4 M HCl					
3 M HCl					

Using Logger Pro, make a graph of $\frac{\text{mol HCl}}{\text{mol Mg}}$ (y-axis) versus time (x-axis) for the four data points following the instructions given below.

Creating a Graph in Logger Pro.

1. If the temperature probe is connected to the computer, you will need to disconnect it.

2. Right click on the graph. Choose: Column Options ; Data Set|X. Label and enter units for the x axes. Clear “Short Name”. Done. Repeat for Data Set|Y.

3. Right click on the graph. Choose: Graph Options; Graph Options tab. Enter a title for the graph. Be sure the title is specific enough so you will know which run of the experiment the printout goes with. In Graph Options, on the right hand side, select Point Symbols and Connect Points by checking the boxes. Uncheck any other boxes that are checked by clicking on them.

4. Enter your “X” and “Y” data into the appropriate columns.

5. Click: Analyze ; Autoscale ; Autoscale

6. Print out a copy of the graph for each lab partner. To do this click: File ; Print. Change the “orientation” to landscape under properties. Be sure that the names of all lab partners are entered in the “Name” section and that the date box is checked.

Observations:

Explanation of your observations (think collision theory). Be sure to include an interpretation of your graph.

Part C. Catalysts

A catalyst is a substance that increases the rate of a chemical reaction without being consumed in the reaction. That is, a catalyst is used to speed up a reaction and is still present, unchanged, at the conclusion of the reaction. A catalyst increases the rate of a chemical reaction by allowing the reaction to occur by a pathway that has a lower activation energy than the activation energy for the pathway followed by the uncatalyzed reaction.

When hydrogen peroxide decomposes, water and oxygen are formed: $2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$.

Place a couple of mL of 3% hydrogen peroxide in a small test tube.

Add a couple of grains of MnO_2 to the hydrogen peroxide in the test tube.

Observations:

Explanation of your observations (think collision theory):

Part D. Surface Area

Obtain a small (about 1 cm) piece of zinc metal, determine its mass, and place it in the bottom of a large test tube.

mass: ____________________

Obtain a similar mass of powdered zinc metal and place it in the bottom of a second large test tube. Pipet 1 mL of 6 *M* HCl into each test tube.

Observations:

Explanation of your observations (think collision theory):

Part E. Temperature

There is a general rule of thumb that the rate of an observable chemical reaction roughly doubles when the temperature increases by 10°C.

The reaction you will be studying in this part of the lab is given by the equation:

$$2\ KMnO_4(aq) + 5\ H_2C_2O_4(aq) + 3\ H_2SO_4(aq) \rightarrow 2\ MnSO_4(aq) + K_2SO_4(aq) + 10\ CO_2(g) + 8\ H_2O(l)$$

An aqueous solution containing the permanganate ion, MnO_4^-, has a purple color. You will follow the rate of the above reaction by determining the time it takes for the purple color of the solution to disappear. You will do the experiment four times: once at room temperature, once at a temperature of about 35°C, once at a temperature of about 45°C, and once at a temperature of about 55°C.

Into each of four large test tubes, put 1 mL of 0.01 *M* potassium permanganate and 4 mL of 3 *M* H_2SO_4 using the preset pumps. Avoid getting either solution on your skin. Place one test tube in the approximately 35°C water bath, one in the approximately 45°C water bath, one in the approximately 55°C water bath, and keep one at room temperature.

Into each of a second set of four large test tubes, put 5 mL of 0.33 *M* oxalic acid, $H_2C_2O_4$ using the preset pumps. Place one test tube in the approximately 35°C water bath, one in the approximately 45°C water bath, one in the approximately 55°C water bath, and keep one at room temperature.

For each run of the experiment, begin keeping track of time as soon as the solutions are poured together. The test tubes should be in the water baths for at least 5 minutes before doing the experiment.

Plug the temperature probe into the Go!Link, and accurately record the temperature of the room. Using the room temperature solutions, pour the oxalic acid solution into the potassium permanganate solution (swirl the solution to help with mixing) and immediately begin keeping track of time so that you know how long it takes for the purple color to disappear.

Using the temperature probe, accurately record the temperature of one of the water baths. Repeat the procedure using the solutions in the water bath and place the test tube containing the mixture back in the water bath after swirling.

Repeat the procedure using the solutions in the other water baths. Be sure to accurately record the temperature of each water bath.

Temperature (^{o}C)	Time (s)

Clear the information for your previous graph by clicking File ; New.

Following the Logger Pro graph generation and printing procedure you used earlier, create a graph of Time (y-axis) versus Temperature (x-axis) for your four data points. Be sure units are included on both axes and the graph has an appropriate title. Click: Analyze ; Autoscale ; Autoscale. Click: Analyze ; linear fit. Print out a copy of the graph including the linear analysis for each lab partner.

Do not clear the information for the previous graph and do not change the axes labels.

Change the title of the graph to indicate a new graph will be created of log(Time) (y-axis) versus Temperature (x-axis) for your four data points.

Choose: Data ; New Calculated Column ; Column Definition tab ; name the column with the title: log(Time) ; clear "Short Name" and clear units. Choose: Functions ; log. Choose: Variables ; Time, Done.

Click on the Y axis **label** and choose log(Time). Click: Analyze ; Autoscale ; Autoscale. Click: Analyze ; linear fit. Print out a copy of the graph including the linear analysis for each lab partner.

Which of these two graphs is most linear? ______________________________________

Equation for the line for the most linear graph: ____

Explanation and interpretation of your graphical results (think collision theory).