Activity 25 - Endothermic & Exothermic Rxns

(H) Enthalpy - Energy which is stored in the Chemical bonds

$$2 H_{2(g)} + O_{2(g)} \longrightarrow 2 H_2O_{(g)}$$

H⦂H
H⦂H

·Ö⦂Ö·

H—Ö—H

H—Ö—H

Breaking 2 H-H bonds   1 O-O bond

Energy Cost
Takes energy to
break bond

making 4 × O-H bonds

Energy gain
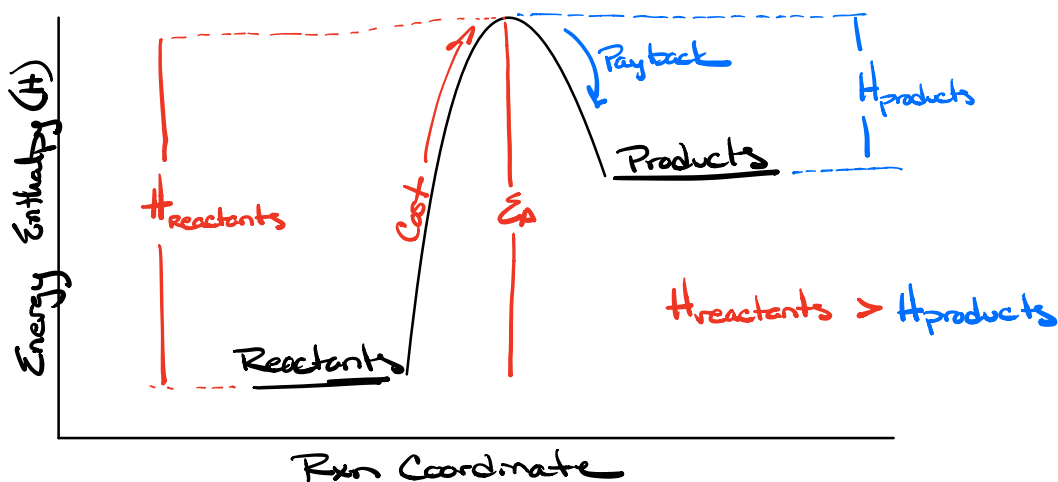Energy is released
when you make
a bond
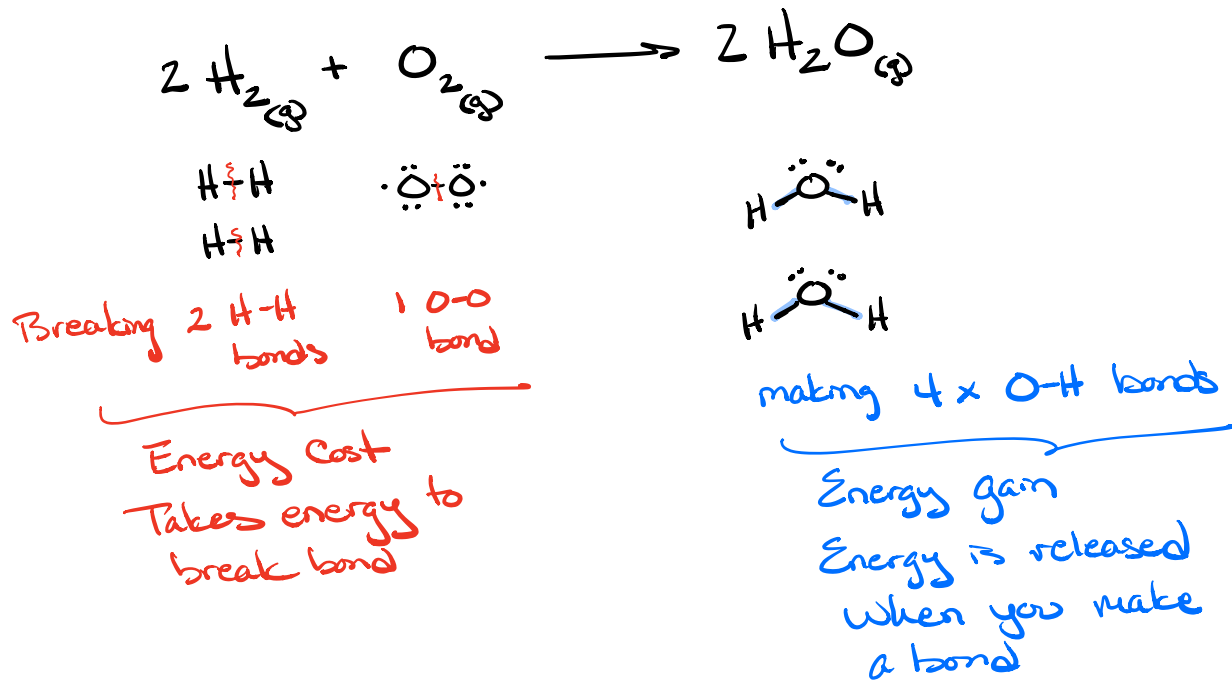
Endothermic Reaction - A reaction that costs more energy than it produces.
It takes more energy to break the bonds of the reactants than is gained from forming the bond of the products
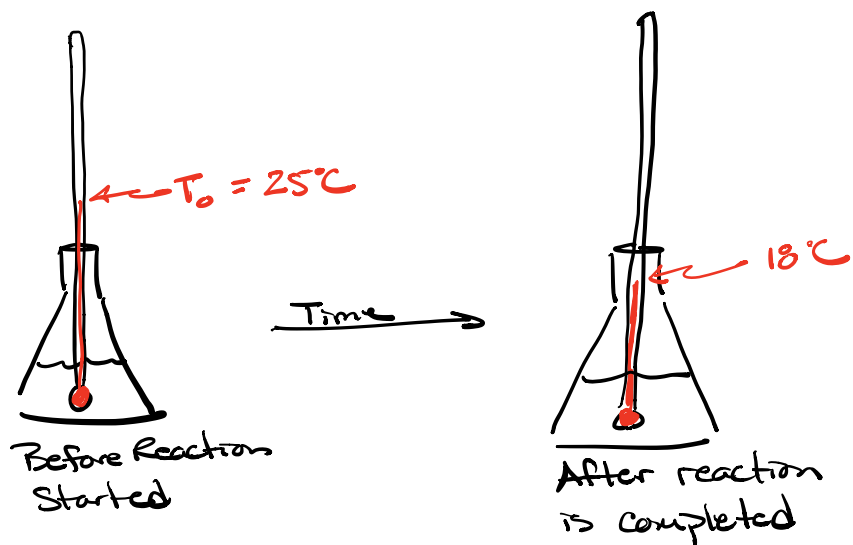
Energy + Reactants ⟶ Products
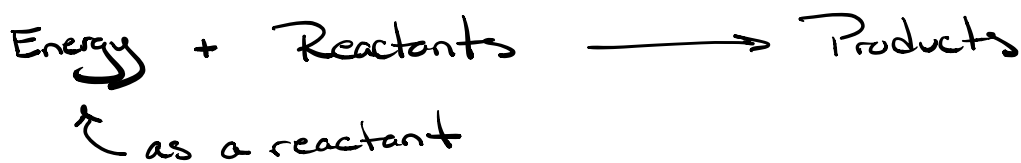
↳ as a reactant

Energy diagram   Endothermic Reaction

E_A = energy of activation = Energy Cost = $H_{reactants}$

Endothermic Reaction

$T_0 = 25°C$

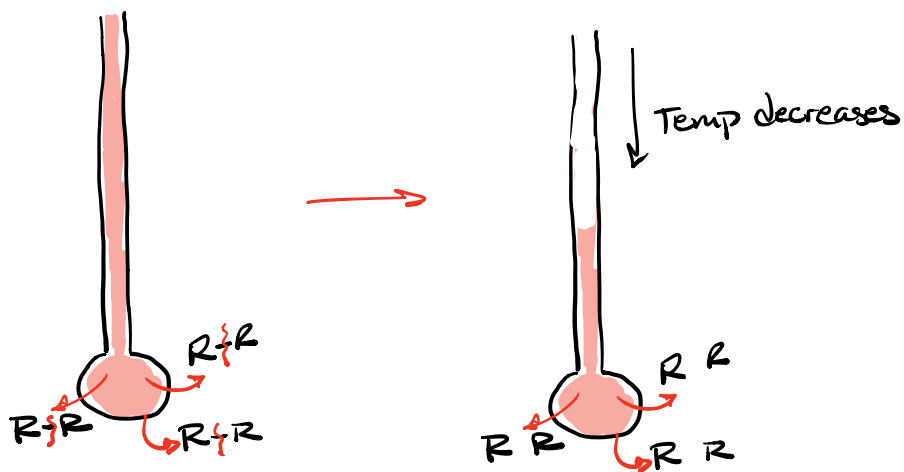Before Reaction Started
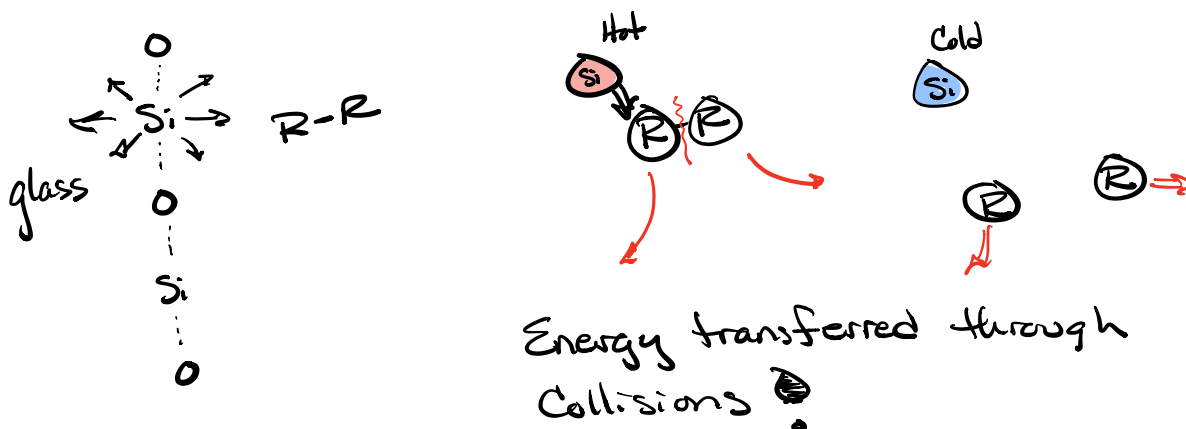
Time →

18°C

After reaction is completed

Reactants

$H_{reactants}$

more energy to break bonds

>

Products

$H_{products}$

Little energy released when new bonds made

Temp decreases

R⌇R   R⌇R   R⌇R   →   R R   R R   R R

glass

O

↖ ↑ ↗
← Si →
↙ ↓ ↘

O

:
Si
:
O

R–R

Hot
Si

R   R

Cold
Si

R

R →

Energy transferred through Collisions 🎤

Endothermic Reaction
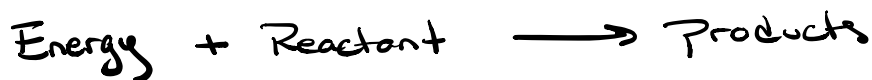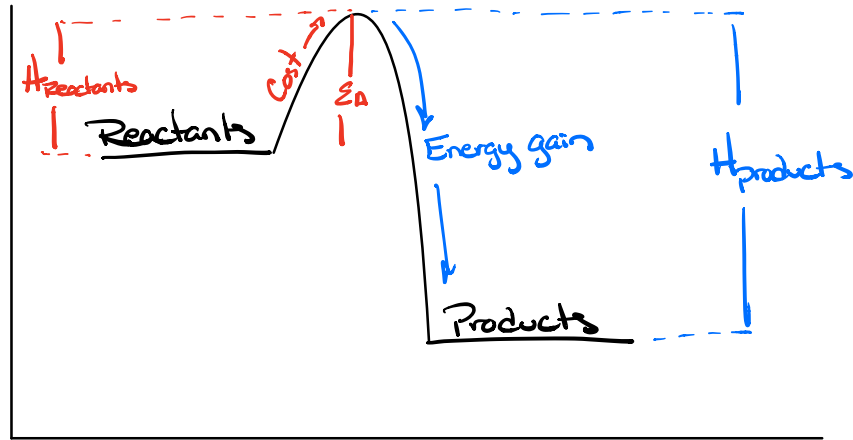

Products

Reactants

Products higher in energy than reactants
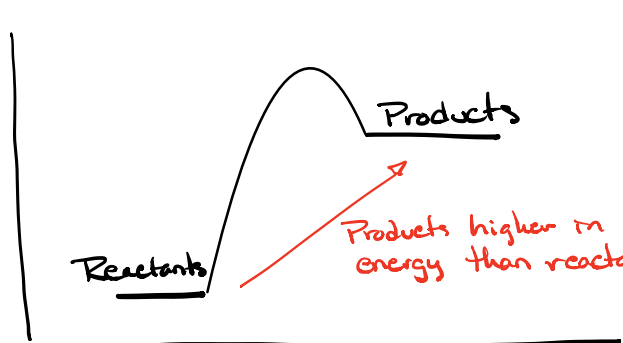
– Energy is pulled from the environment to break bonds

– Energy of the System goes down ~~Environment~~
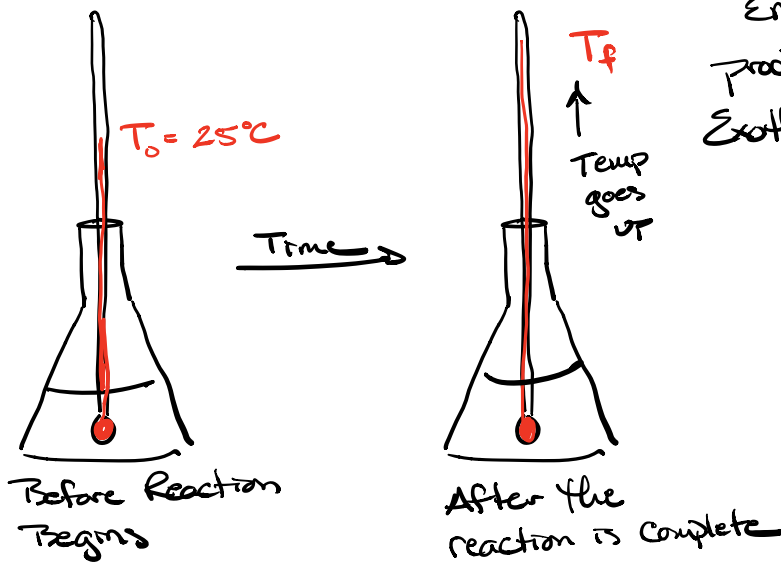
– Temperature goes down

Energy + Reactant ⟶ Products

Exothermic Reaction

$H_{reactants}$ < $H_{products}$
more energy is produced

Reactants $\longrightarrow$ Products + Energy

Energy is a product of an Exothermic Reaction

$T_0 = 25°C$

T_f

Temp goes up

Time $\longrightarrow$

Before Reaction Begins

After the reaction is complete

Cold   moving Slowly   Hot

(R) →←(R)   →   (P-P) ⟹ fast

Collide

Glass Thermometer

Si   Si
   O   O   Hot
(Si) →   →(Si)→   P-P ↗ Slowly
   O   ← P-P   O
Si   Si
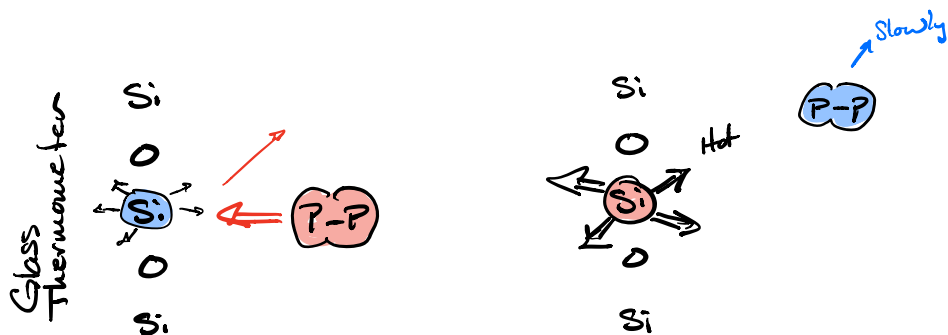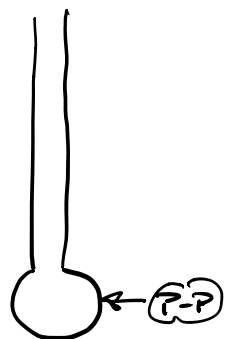
Energy transferred in Collision

Exothermic Reaction

Reactants

Energy
is released   Products
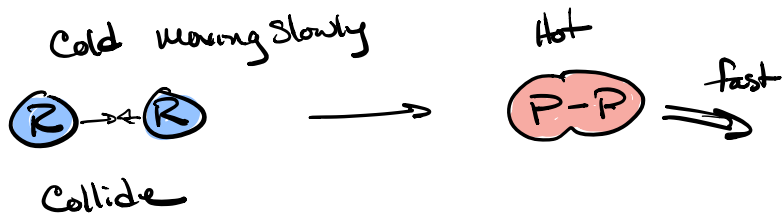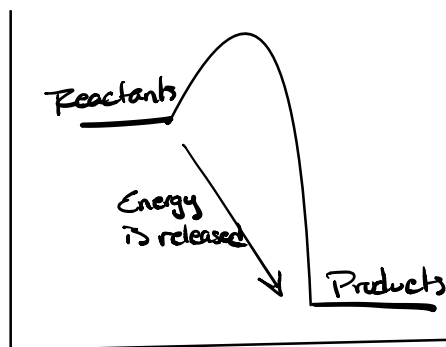
- In the making of bonds
  energy is given off
  to the environment

                              Environment
- Energy of the System
  goes up

- Temperature goes up

Environment

System
Solution
Run
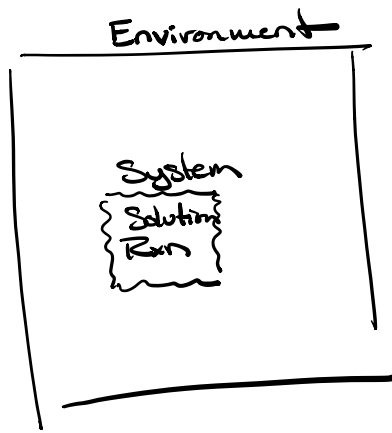
# Activity 25 - Endothermic and Exothermic Reactions

Introduction

Many chemical reactions give off energy. Chemical reactions that release energy are called *exothermic* reactions. Some chemical reactions absorb energy and are called *endothermic* reactions. You will study one exothermic and one endothermic reaction in this experiment.

In Part I, you will study the reaction between citric acid solution and baking soda. An equation for the reaction is:

$$H_3C_6H_5O_{7(aq)} + 3\ NaHCO_{3(s)} \longrightarrow 3\ CO_{2(g)} + 3\ H_2O_{(l)} + Na_3C_6H_5O_{7(aq)}$$

In Part II, you will study the reaction between magnesium metal and hydrochloric acid. An equation for this reaction is:

$$Mg_{(s)} + 2\ HCl_{(aq)} \longrightarrow H_{2(g)} + MgCl_{2(aq)}$$
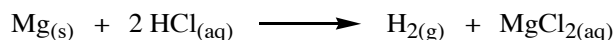
Another objective of this experiment is for you to become familiar with Logger *Pro*. In this experiment, you will use Logger *Pro* to collect and display data as a graph or table, analyze your experimental data values, and print a graph or data table.

Safety

Wear safety glasses at all times!
Act in accordance with the laboratory safety rules of Cabrillo College.
Avoid contact with all chemical reagents and dispose of reactions using appropriate waste containers.

Materials

Power Macintosh or Windows PC	Styrofoam cup
Vernier computer interface	250-mL beaker
Logger *Pro*	citric acid, $H_3C_6H_5O_7$, solution
Temperature Probe	baking soda, $NaHCO_3$
50-mL graduated cylinder	hydrochloric acid, HCl, solution
balance	magnesium, Mg

Experimental Procedure

A. Citric Acid plus Baking Soda

1. Place a Styrofoam cup into a 250-mL beaker as shown in Figure 1. Measure out 30 mL of citric acid solution into the Styrofoam cup. Place a Temperature Probe into the citric acid solution.
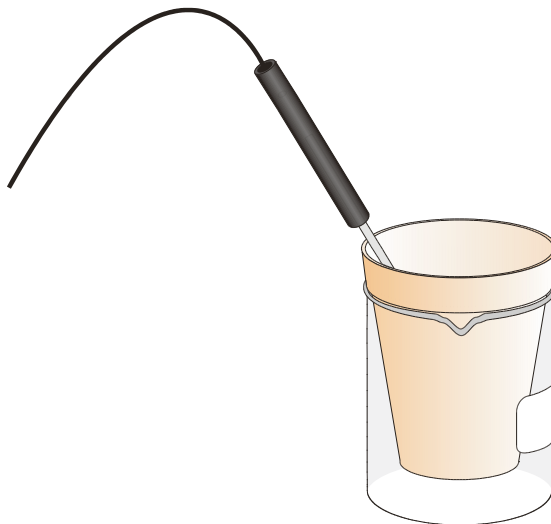

Figure 1. Experimental setup.

2. Prepare the computer for data collection by opening the Experiment 1 folder from the *Chemistry with Computers* folder of Logger *Pro*. Then open the experiment file that matches the probe you are using. The vertical axis has temperature scaled from -10 to 40°C. The horizontal axis has time scaled from 0 to 300 seconds.

3. Weigh out 10.0 g of solid baking soda on a piece of weighing paper.

4. The Temperature Probe must be in the citric acid solution for at least 30 seconds before this step. Begin data collection by clicking ⏸▶Collect. After about 20 seconds have elapsed, add the baking soda to the citric acid solution. Gently stir the solution with the Temperature Probe to ensure good mixing. Collect data until a minimum temperature has been reached and temperature readings begin to increase. You can click on ⏸● Stop to end data collection or let the computer automatically end it after 300 seconds.

5. Dispose of the reaction products as directed by your teacher.

6. To analyze and print your data:

    a. Click the Statistics button, 📊. In the statistics box that appears on the graph, several statistical values are displayed for Temp 1, including minimum and maximum. In your data table, record the maximum as the initial temperature and the minimum as the final temperature. Close the statistics box by clicking the upper-right corner of the box.

    b. To confirm the minimum and maximum temperatures, use the scroll bars in the Table window to scroll through the table to examine the data. Compare the minimum and maximum data points to those you recorded in the previous step.

    c. Print a copy of the Table window. Enter your name(s) and the number of copies.

    d. You will often want to change the scale of either axis of the graph. There are several ways to do this. To scale the temperature axis from 0 to 25°C instead of the present scaling, click the mouse on the "40" tickmark at the top of the axis. In place of the "40", type in "25" and press the Enter key. Notice that the entire axis readjusts to the change you made. Use the same

method to change the "-10" tickmark to "0". Note: A second option is to click the Autoscale button, ⊡. The computer will automatically rescale the axes for you.

   e. You can also expand any portion of the graph by zooming in on it. Select the area you want to zoom in on. Do this by moving the mouse pointer to the beginning of this section of data—press the mouse button and hold it down as you drag across the curve, leaving a rectangle. Then click the Zoom In button, ⊡. The computer will now create a new, full-size graph that includes just the region inside the rectangle. You can reverse this action by clicking the Undo Zoom button, ⊡.

   f. When you again collect data in Part II of this experiment, the data will be collected as Latest run, the *most recent* set of data you have collected. The original Latest run will be lost if it is not saved or stored. Choose Store Latest Run from the Data menu to *store* Latest as Run 1, then save or print it later. Note that the line for Run 1 is thinner than it was for Latest. To hide the curve of your first data run, click the Temperature vertical-axis label of the graph, and uncheck Run 1. Click ⊏ OK ⊐.

B. Hydrochloric Acid Plus Magnesium

7. Manually rescale the vertical axis to the original temperature scale of -10 to 40°C. To do so, click the mouse on the bottom tickmark and type in "-10". Then click on the top tickmark and type in "40".

8. Measure out 30 mL of HCl solution into the Styrofoam cup. Place the Temperature Probe into the HCl solution. Note: The Temperature Probe must be in the HCl solution for at least 45 seconds before doing Step 11. **CAUTION:** *Hydrochloric acid is caustic. Avoid spilling it on your skin or clothing. Wear chemical splash goggles at all times. Notify your teacher in the event of an accident.*

9. Obtain a piece of magnesium metal from the teacher.

10. Begin data collection by clicking ⊏▶Collect⊐. After about 20 seconds have elapsed, add the Mg to the HCl solution. Gently stir the solution with the Temperature Probe to ensure good mixing. **CAUTION:** *Do not breathe the vapors!* Collect data until a maximum temperature has been reached and the temperature readings begin to decrease.

11. Dispose of the reaction products as directed by your teacher.

12. To analyze your Part II data:

   a. Change the appearance of the graph by double-clicking anywhere on the graph to bring up the Graph Options dialog. Check the box in front of Point Protector Every 1 Point—a point protector will now outline each data point on the graph. Click ⊏ OK ⊐.

   b. Instead of scrolling through the Table window in this trial, click the Examine button, ⊡. The cursor will become a vertical line. As you move the mouse pointer across the screen, the temperature and time values corresponding to its position will be displayed in the box at the upper-left corner of the graph. Scroll across the initial 3-4 points to determine the initial temperature. Record the initial temperature in the data table. Move the mouse pointer across the peak of the temperature curve to determine the maximum temperature, and record it as the final temperature in your data table. To remove the examine box, click the upper-right corner of the box.

   c. It is also possible to calculate statistics just for a portion of your collected data. To do so, you must first *select* the data you are interested in. For example, you might want to find the average (or mean) of the first few data points to use as an initial temperature, instead of using the minimum value. Select the flat portion of the curve—move the mouse pointer to time 0 and drag across the flat part of the curve. Now click the Statistics button, ⊡, and note the mean temperature value in the statistics box on the graph. This value is the mean of only the selected data points. When you are done, click on the upper-right corner of the statistics box to remove it.
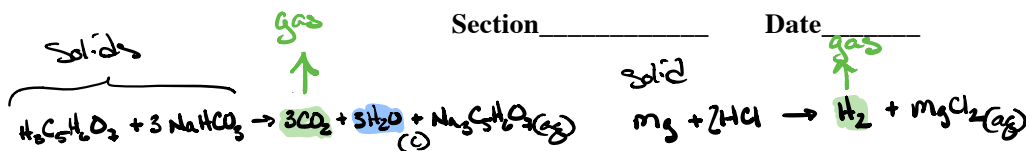
13. To print a graph of temperature *vs.* time showing both data runs:

   a. Click the Temperature vertical-axis label of the graph. To display both temperature runs, check the Run 1 and Latest boxes. Click [OK].

   b. Label both curves by choosing Make Annotation from the Analyze menu, and typing "Endothermic" (or "Exothermic") in the edit box. Then drag each box to a position near its respective curve.

   c. Print a copy of the Graph window. Enter your name(s) and the number of copies of the graph you want.

14. Save the temperature and time data from both data runs. Choose Save As from the File menu and give the file a distinct name. As directed by your teacher, choose a location for the file, and click [OK].

Activity 25 - Endothermic and Exothermic Reactions Worksheet

Name_____

Section_____ Date_____

Data Table

solids

gas

solid

gas

$H_2C_5H_6O_7 + 3\ NaHCO_3 \rightarrow 3CO_2 + 3H_2O + Na_3C_5H_6O_7(aq)$ (c)

$Mg + 2HCl \rightarrow H_2 + MgCl_2(aq)$

|	Part I		Part II	
Final temperature, t_2	16.2	°C	27.6	°C
Initial temperature, t_1	22.0	°C	22.0	°C
Temperature change, Δt		↓ °C		↑ °C

Observations $\Delta T = T_f - T_I$ watch your sign of temp

+ or −

Processing the Data

1. Calculate the temperature change, Δt, for each reaction by subtracting the initial temperature, t_1, from the final temperature, t_2 ($\Delta t = t_2 - t_1$).

2. Tell which reaction is exothermic. Explain.

3. Which reaction had a negative Δt value? Is the reaction endothermic or exothermic? Explain.

4. For each reaction, describe three ways you could tell a chemical reaction was taking place.

5. Which reaction took place at a greater rate? Explain your answer.   Rate = time
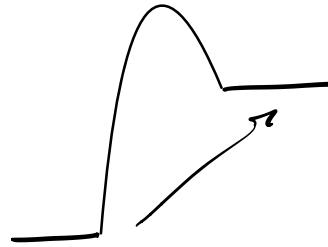   → which one went faster

Exothermic
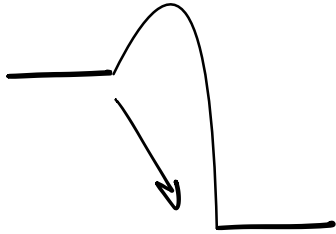
energy of System has gone down and that energy has been given to the environment as heat

Temp ↑ up

Endothermic

energy of the System has gone up. Energy from the environment was used to make the products

Temp ↓ down