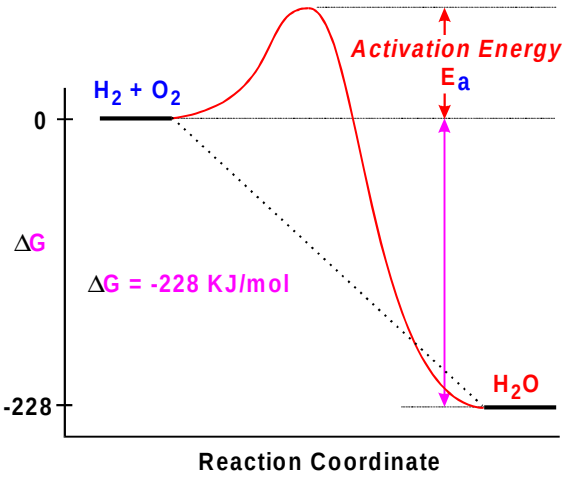
Kinetics, Equilibrium & Catalysis

The rates of chemical reactions as a function of temperature will be discussed via the use of light sticks at 3 different temperatures and the H_2/O_2 balloon explosion. The concept of activation barriers to chemical reactions will thus be introduced. The catalytic decomposition of H_2O_2 and oscillating Iodine reaction will also be performed along with the chemical principles involved.

Stuff:

- **thermos bottle (or insulated container) (*you provide*)**
- **boiling hot water put in thermos (*you provide*)**
- **ice (*you provide*)**
- **water in container (*you provide*)**
- **large disposable plastic or aluminum tray (e.g., turkey pan) (*you provide*)**
- **roll of paper towels for cleaning up messes (*you provide*)**
- **clear bottle or glass about 6" high by 2-3" in diameter (*you provide*)**
- **butane stick lighter (the kind used to light bar-b-q's) or long matches (*you provide*)**
- **small amount of dishwashing detergent liquid (*you provide*)**
- **3 clear glass jars or glasses the same size – big enough to hold one light stick (*you provide*)**
- 3 light sticks (we will provide)
- 3 balloons – H_2, O_2 and H_2/O_2 mixture (we provide)
- small amount of potassium or sodium iodide solution (we provide)
- oscillating iodine clock reaction kit (we provide – **<u>return jars after experiment</u>**!!)

H_2/O_2 balloon experiment: You have three small balloons, one with pure oxygen, one with pure hydrogen, and one with a 2:1 H_2/O_2 mixture. Using a butane stick lighter (one of those long ones for lighting charcoal fires) ignite the O_2 balloon, then the H_2 balloon, and finally the H_2/O_2 balloon. Make sure that the balloons are at arms length when you ignite them. The H_2/O_2 balloon with detonate extremely loudly. That is why it is not very large. Discuss how the reaction of H_2 and O_2 is spontaneous, that is, thermo-dynamically very downhill. Even though this reaction wants to take place it doesn't until you add some energy (the flame). Sketch out the following diagram and discuss the activation barrier and how it stops reactants from reacting immediately.



Light sticks & Temperature experiment: put ice water in one beaker, room temperature water in the second, and hot (not boiling) water from the thermos in the third. Put one light stick in each beaker and let sit for 5 mins (do this before you start the H_2/O_2 balloon experiment). Now you can bend and snap them to activate them. The light sticks will glow at very different intensities corresponding to the temperature of the water that it they are sitting in (the hotter the temperature the faster the chemical reaction that makes the light). Discuss the effect that temperature has on the rate of chemical reactions and how it ties into the activation barrier (previous demo). Ask them which light stick will use up the chemicals reacting to make the light first. Discuss the concept that the faster the reaction the sooner you use up all the reactants and the reaction will stop.

Bring up the old wives tale *"feed a fever, starve a cold"* or is it *"starve a fever, feed a cold."* Ask the students about which one they think is more correct with respect to the fever (ignore the cold part of the saying). Discuss the effect that a fever has on the body and how the higher temperature is the body's way of speeding up your metabolism to get your immune system working at a higher rate. So a fever is your bodies way of speeding up your immune system to fight off infections and disease. Naturally, if the fever goes too

high you will die. Similarly, if your body temperature drops more than about 6ºF all the chemical reactions slow down to the extent that you can die (hypothermia).

Catalytic decomposition of hydrogen peroxide (H_2O_2): Pour the 30% H_2O_2 (careful: this is relatively concentrated hydrogen peroxide and it is potentially dangerous – wear safety glasses) into the glass container and add a couple of squirts of liquid dish washing detergent and mix them together. Place this container on the shallow pan to catch the bubbles that will be produced in the next step. Add the NaI (or KI) solution. The iodide anion catalyzes the decomposition of H_2O_2 to H_2O and O_2 (try writing out the balanced chemical equation or have the class try to balance it). The O_2 produced causes zillions of bubbles to form from the dish washing liquid. This causes a column of very fine bubbles to rise out of the container and spill into the catch pan. Steam will also be produced from the exothermic nature of the reaction. Discuss how a catalyst speeds up a chemical reaction by lowering the activation barrier for that reaction. Discuss how your body has lots of bio-catalysts (enzymes) that speed up many of the too slow metabolic reactions to keep you alive.

Oscillating Iodine Reaction: If you are given a manufactured demonstration kit, follow the instructions in the box. If you get a homemade "kit" from us it will contain 3 bottles with the solutions of chemicals that you need to mix together to start the reaction. Add the solutions in the two smaller bottles (**A** & **B**) to the solution in the larger bottle (**C**). Swirl the contents to mix them up. The oscillating reaction should start in about a minute and change colors about 15-20 times.

Use the reaction scheme shown to the right to discuss how the reaction oscillates between IO_3^- (iodate anion, colorless), I_2 (iodine, gold-yellow), and I_3^- (triiodide anion), which forms a deep blue-purple complex with starch. The H_2O_2 acts as an oxidizing agent (ripping electrons away from the I_3^- anions to produce IO_3^-, while the malonic acid donates electrons to IO_3^- to first form iodine, and then I_3^- anions.

The key in this reaction is that H_2O_2 only slowly directly reacts with malonic acid and they both react more rapidly with iodate/iodine/triiodide anions. This keeps the reaction oscillating until you run out of H_2O_2 or malonic acid.