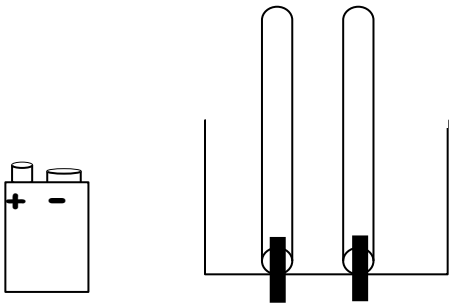
LAD G5 (pg 1 of 2) Decomposition Reactions

1. Electrolysis of Water



a. Observations:
Bubbles form at both electrodes. More bubbles are forming at the electrode connected to the negative terminal on the battery. In fact it is twice as much gas forming, indicating it is hydrogen. A flaming splint test will give a pop confirming the presence of hydrogen. The negative end of the battery is trying to "spew" out electrons. This is the site that the hydrogen forms at because the hydrogen is trying to gain electrons (become reduced) as it turns into hydrogen gas.

b. Reaction:
$2\ H_2O_{(L)} \rightarrow\ 2\ H_{2(g)}\ +\ O_{2(g)}$

c. Water doesn't conduct electricity very well, so the liquid is a sodium bicarbonate solution. Write out the chemical formula for sodium bicarbonate and write an equation that demonstrates what happens when put into water. Explain how it can help conduct electricity.
$NaHCO_{3(s)} \rightarrow Na^+ + HCO_3^-$ dissolves into ions which help to carry the charge and complete the electrical circuit, keeping the electrons flowing.

d. What substances are in the bubbles?
The bubbles are NOT air bubbles. They are hydrogen gas bubbles and oxygen gas bubbles

e. What are the relative amounts of gas forming in each tube? Why is there more of one gas than the other? Which gas is which?
The tube with twice as much is hydrogen, and the tube with half the amount is oxygen. Since water is mad of two H's for every one oxygen and both gases are diatomic, it would be expected that there twice as much of the hydrogen gas forms.

f. Which gas is forming at the – end of the battery? Explain why this would be occurring at the negative end.
The hydrogen is reduced in this reaction – gaining electrons. The negative terminal of the battery is trying to "spew" out electrons. The oxygen is oxidized at the opposite electrode.

2. Hydrogen Peroxide Genie

a. Observations:
Hydrogen peroxide placed in the test tube exhibits very little bubble formation, and little evidence of decomposition. When place in the 2 L bottle and the (heterogeneous) catalyst, MnO_2 powder is added, the decomposition is very rapid.

b. Reaction:
$2\ H_2O_{2(L)} \rightarrow\ 2\ H_2O_{(L)}\ +\ O_{2(g)}$ This a redox reaction.

c. Water vapor is colorless, so it's not water vapor that you see coming out of the top of the bottle. What is it?
Water vapor as you breath it out is invisible. Your body is at 35ºC and the room is 22ºC, so there is not much difference in temp causing your breath to condense. When you go outside in the winter and the air is below 0º you see condensing water vapor, making a small cloud. The decomposition of hydrogen peroxide reaction is so exothermic, the heated water turns to vapor, which cools when it hits the room temp (cool compared to the heated reaction). Thus the plume that you see coming out of the top of the bottle is condensed water vapor. Oxygen and air would also be coming out too, but of course you can not see those gases.

d. What landed on the lab bench?
Lots of fine water droplets and some of the powdered catalyst blew out and landed on the lab bench.

e. What caused the vapor/gas to rush out of the top of the bottle?
The reaction generates oxygen gas, and the heat from the reaction causes the formation of water vapor, which condenses into tiny droplets The heat generated from this exothermic reaction also causes the air to expand. All of this extra and expanding gas need room, so it pushes out the opening in bottle.

f. What is the temperature of the bottle after the reactions? What happened to the shape/size of the bottle immediately after the reaction? Why? Is this reaction exothermic or endothermic?
This decomposition reaction is very exothermic, giving off lots of energy and raising the temperature of the contents in the bottle. This increase in temp causes bonds in the plastic polymer break and causes the bottle to shrink.

g. When the cap was put on after the reaction the bottle appears to slowly crush inward. Why?
As soon as the initial rush of gas pushes out of the bottle, and the reaction ends, the gases remaining inside the bottle begin to cool off. This causes the gases begin to contract, and ordinarily air would go back in the bottle to "fill it up

again" but since the cap is put back on, the passage between the outside air and the bottle is cut off. The air outside pushes inward on the sides of the sealed bottle and cause it to crush inward.

h. H_2O_2 has an unstable O—O bond. It is sold in brown bottles. Why?

The O—O bond (peroxide bond) is unstable and the energy from light will cause it to decompose (slowly). This would be bad if it occurred in the store because the customer would not be getting the hydrogen peroxide that they paid for. Furthermore, the generation of oxygen gas would cause the top to pop off.

3. Elephant Toothpaste – A Discussion About Catalysts

a. Observations:

The addition of the homogeneous catalyst, a solution of potassium iodide caused the hydrogen peroxide to decompose very quickly. There was a big fluff of foam that rose up out of the test tube and landed on the tray. Then it expanded even more. It was steaming and felt hot. When the glowing splint was plunged into the foam, it relit, indicating the presence of oxygen.

Introduction to catalysts

Catalysts are agents that change the speed of a chemical reaction without undergoing a permanent chemical change itself in the process. They affect the collisions that cause the reaction to occur. Catalysts play a crucial role in our lives. The physiology of most living species depends on enzymes, which are protein molecules that act as catalysts, increasing the rates of selected biochemical reactions. Much industrial chemical research is devoted to the search for new and more effective catalysts for reactions of commercial importance. *When reactions happen faster, companies make more money.* Chemists sign contracts to keep them from engaging in chemical espionage. Extensive research efforts are devoted to finding means of inhibiting or removing certain catalysts that promote undesirable reactions, such as those that corrode metals, age our bodies, and cause tooth decay.

Catalysts fall into two general categories. A catalyst that is present in the same physical state as the reacting molecule is a homogeneous catalyst. A heterogeneous catalyst exists in a different physical state from the reactant molecules, usually as a solid in contact with either gaseous reactants or with reactants in a liquid solution. A heterogeneous example is the catalytic converter that is part of your exhaust system underneath your car. Metal oxides in the catalytic converter help to react any unburned gasoline that gets out of the engine. The metals used in these metal oxides are platinum, palladium, and rhodium, all of which are more expensive than gold, and what make the catalytic converter so expensive to replace.

The reaction that occurred to cause the "Elephant Toothpaste"

The test tube contained hydrogen peroxide, H_2O_2 (with dish soap added for effect), an unstable molecule which was catalyzed by the I^{-1} in the KI solution. The mechanism for the reaction occurs in two steps which occur at different speeds.

b. In the space below, add the two reaction steps to get the overall reaction.

c. Then subtract any particles that occur on both sides of the reaction to write the net reaction.

step 1 (slow reaction) $H_2O_{2(aq)} + I^-_{(aq)} \rightarrow IO^-_{(aq)} + H_2O_{(L)}$

step 2 (fast reaction) $H_2O_{2(aq)} + IO^- \rightarrow H_2O_{(L)} + O_{2(g)} + I^-_{(aq)}$

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overall reaction $2\ H_2O_{2(L)} + I^-_{(aq)} + IO^- \rightarrow IO^-_{(aq)}\ \ 2\ H_2O_{(L)} + O_{2(g)} + I^-_{(aq)}$

net result $2\ H_2O_{2(L)} \rightarrow 2\ H_2O_{(L)} + O_{2(g)}$

d. What do the two reactions show you about the catalyst, I^{-1} ?

The catalyst gets used in the slow reaction and then comes back in the fast reaction. It is not used up during the overall reaction.

e. A compound that forms during a reaction, and then gets used up before the reaction is over is called and intermediate. Which substance is the intermediate in this reaction?

The IO^- is an intermediate. It is not a reactant that is put into the reaction, but an intermediate is a substance forms from the reaction in one step and then is used up in a subsequent step.

f. What gas was formed inside the bubbles? What test was done to help confirm the presence of this gas?

The gas that caused the soap suds to foam up was oxygen. The glowing splint test relit to confirm the presence of oxygen.

g. What caused the foam to form from the soap suds?

The formation of the oxygen gas caused bubbles which caused the soap suds to make foam.

h. As the reaction proceeded, did it warm up or cool down? How could you tell? Is this an exothermic or endothermic reaction?

The suds appeared to be steaming and felt warm. As in the "hydrogen peroxide genie" this same reaction is exothermic – gives off energy.