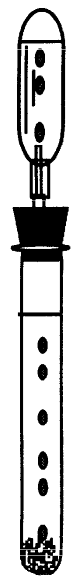
I used to be Snow White
but I drifted. ---Mae West

Chemical Behavior of Common Gases

While we tend not to pay too much attention to gases unless they are in some way unpleasant, there are gases all around us at all times and they have chemical properties which are often important in our personal space as well as the larger environment. So far in the course we have used the presence of gases to identify some kind of chemical change (hydrogen displacement, or oxidation by nitric acid are examples). Now you will have an opportunity to make some gases not as by-products but rather as the subjects of interest.

In the teaching laboratory the collection of small amounts of gases for study has usually been accomplished by water displacement, i.e., the gas is generated by some suitable reaction and then is transported by a tube into an inverted container filled with water. As the gas bubbles in, the water is displaced. This method was meant to ensure that the gas would be fairly pure (if somewhat "wet" since water vapor would collect along with the gas owing to water's vapor pressure at room temperature). Gases which are soluble in water have been collected by displacement of air (this works for ammonia and chlorine).

In this experiment you will use a modern mini-scale adaptation of the water-displacement method. The gas generator consists of a small test tube with a one-hole stopper and short delivery tube. The collection "bottle" is the dropper end of a beral pipet as shown at the right. The dropper can be filled with a distilled water bottle and surface tension will keep the water from running out when it is inverted. By leaving a little water in the neck of the dropper bulb when you have collected a gas sample, you can store it "sealed" while you collect others. The bulbs stand up nicely, neck-down, in the small wells of a 24/96-well micro-plate. Notice in the diagram that the liquid level is fairly high in the test tube (about 3/4). This is done so that the time required to flush out air before only gas comes out of the tube is minimized. With this apparatus you can generate and collect most gases that are minimally soluble in water. Because water will be displaced from the collection bulb it is best to hold the generator in a small beaker to catch the spills.



Adapted from: Micro Action Chemistry, 2nd ed., vol 1, C.V. Ciardullo, C.M., *Flinn Scientific*, 1992

Preparing to experiment

In addition to three gas generators and a number of collection bulbs you will be given the following supplies:

1. 4 M HCl
2. 6% H_2O_2 (hydrogen peroxide)
3. limewater solution (saturated $Ca(OH)_2$)
4. marble chips (mainly $CaCO_3$)
5. granular Zn
6. MnO_2
7. bubble solution
8. 24/96 combo-well microplate
9. toothpicks

Design an experiment to collect and test samples of carbon dioxide, oxygen, and hydrogen. The tests to be performed include:

a. unique ID test for each gas
b. ability to support combustion
c. density relative to air
d. volume ratio for optimum $H_2 + O_2$ reaction

For more information on these tests and the generation reactions, see the **Technique** section that follows.

Pre-lab take-home quiz

1. Write balanced molecular reactions for the gas generation processes described in the **Technique** section.

2. The unique ID tests for carbon dioxide and hydrogen involve simple chemical reactions. For carbon dioxide, reaction with $Ca(OH)_2$ produces insoluble $CaCO_3$ and water. In the case of hydrogen gas, reaction with oxygen (in the air or added) produces water. Write balanced molecular reactions for these processes.

3. Explain why the ID test for oxygen gas cannot be readily described by a single chemical reaction. [*hint*: is wood a single substance?]

Technique

1. generating the gases

One marble chip in a test tube with HCl will generate CO_2 for some time, enough for you to collect the several bulbs you will need for the tests.

Hydrogen gas is easily made by using about 0.5 g of granulated Zn and HCl. **KEEP THIS GAS GENERATOR AT A RESPECTABLE DISTANCE FROM OPEN FLAMES.**

Oxygen has traditionally been made by heating $KClO_3$ to decomposition but this method has drawbacks (the heat needed) and dangers ($KClO_3$ can explode if impurities are present). In this experiment you will use the decomposition of H_2O_2 (to give water and O_2). This reaction occurs very slowly on its own. To be practical it must be sped up. To do this we use a *catalyst*, MnO_2. This substance accelerates the decomposition without being consumed (a catalyst is not even written as part of a balanced equation). We will talk more about catalysts in the second semester. About 1 g of MnO_2 is plenty. **KEEP THIS GAS GENERATOR AT A RESPECTABLE DISTANCE FROM OPEN FLAMES.**

2. the ID tests

The classic ID test for CO_2 is its reaction with limewater solution. Half fill a large well in the 24/96 plate with limewater solution. Take one of the gas-filled pipets and place its mouth under the surface of the limewater solution. Squeeze the gas into the solution quickly and all at once.

Oxygen is generally identified by its ability to support combustion. Light a wooden toothpick and blow out the flame so that the wood is still glowing. Then insert the toothpick into a bulb of gas held horizontally. This can be a little tricky because water clinging to the short neck of the bulb can extinguish the glowing wood if it touches it. Be patient and keep trying.

Hydrogen is detected by its reaction with oxygen in the air in the presence of a flame or spark. Light a wooden toothpick. Holding a bulb of hydrogen gas horizontally, mouth near the burning toothpick, quickly squeeze the bulb of gas.

3. Other tests for all gases

a) relative density: place a film of bubble solution across the mouth of the tube. When a small bubble forms, raise the apparatus just above your head and blow gently to dislodge the bubble without breaking it. Does it sink or rise? Again, some patience is needed here. Just keep trying.

b) ability to support combustion: this is the same as the ID test for oxygen (glowing toothpick inserted into horizontal bulb) and should be done on the other gases also

4. hydrogen/oxygen gas combination ratio experiment

Collect hydrogen and oxygen in the same bulb at various volume ratios (1:1, 1:2, 2:1, etc.). To test each combination, bring the bulb close to a bunsen burner with a small flame, holding the bulb mouth down. At about 2 cm away from the flame quickly squeeze the bulb. You should be able to distinguish the result for various ratios and perhaps even verify Avogadro's Law. **CAUTION: MIXTURES OF HYDROGEN AND OXYGEN ARE EXPLOSIVE. FOLLOW THESE DIRECTIONS PRECISELY.**

Analysis

1. Summarize (in a table or other succinct form) the results of the ID and other tests.

2. Which volume ratio produced the loudest or most powerful explosion? Why is this? How does this result relate to Avogadro's Law?