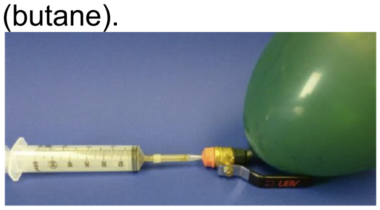
Exploding Bubbles: Stoichiometry is Fun!

The role and importance of stoichiometry in optimizing chemical reactions is demonstrated in this combustion experiment. The limiting reagent concept can also be clearly illustrated by this experiment. Students will mix O_2 and an “unknown” combustible gas in various ratios using a plastic syringe, inflate a soap bubble, ignite it, and observe the loudness of the resulting explosion. The loudest explosion will indicate the optimum reaction ratio, and hence stoichiometry of the combustion reaction. The key to this experiment is the nature of the Gas Laws that directly relate volumes of gases, at the same temperature and pressure, to molar amounts. Therefore, two volumes of Gas A and one volume equivalent of Gas B represent a 2:1 molar ratio. From the loudest explosion gas ratio students can deduce the nature of the unknown combustible gas.

Materials:

- Paper towels for clean-up (*you provide*)
- 10 brass valves with rubber septa with inflated color-coded balloons attached (*we provide*, *return valves*). Gases used: O_2 (green or blue balloons); possible combustible gases: H_2; CH_4 (methane, natural gas); $H_2C{=}CH_2$ (ethylene); $CH_3CH_2CH_3$ (propane), or $CH_3CH_2CH_2CH_3$ (butane).




- 10 butane stick lighters (*we provide*, *please return*)
- 10 small plastic bottle caps (*we provide*, *please return*)
- 1 plastic bottle with a dishwater soap solution (*we provide*, *please return*)
- 30 Safety Glasses (*we provide*, *please return*)
- 35 data collection forms (*we provide*)

Safety Notes: You are representing LSU. Please be professional and safety conscious. 90% of safety is using good common sense and being cautious. **Wear safety glasses when working with chemicals.** You must practice the experiment before attempting it as a class demonstration. You will gain confidence and appear more professional to your audience.

Two main safety concerns with this experiment:

1. Keep the combustible balloons away from flames!! I recommend scattering the oxygen and combustible gas balloons around the periphery of the room away from the student groups working with the bubbles.
2. After the students inflate a bubble using the plastic syringe with the gas mixture it is **very important that they withdraw the tip of the syringe and move it away from the bubble before igniting the bubble with the butane stick lighter**. If they ignite the bubble while the tip of the syringe is still in the bubble the explosion will travel up the syringe tip into the remaining gas in the syringe and blow the syringe apart. We don’t want to do this!! So, stress to the students that the person working the syringe and

blowing the bubble removes the syringe before the person working the butane stick lighter ignites the bubble!!

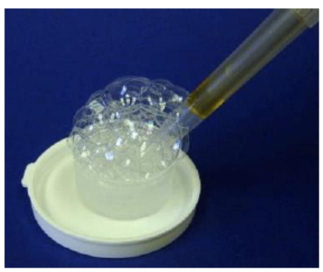
The exploding bubbles are quite safe since the bubble solution is non-toxic and can't really do any damage. The bubbles can only be blown so large before they burst, limiting the students from making too large bubbles that could be dangerous. Needless to say, students should keep their faces from getting too close to the bubbles.

Initial Setup

Students should work in groups of 2 or 3 for this experiment. Each group should get one plastic syringe, a bottle cap with a small plastic flat cap to catch any spilled soap solution, and one butane stick lighter (test all the butane stick lighters beforehand to make sure they are working OK). The group should add soap solution to their bottle cap to fill it about ¾ of the way.

Once they return to their desks they should take turns practicing blowing an air bubble with the syringe. The technique for blowing a single good-sized bubble is to insert the syringe tip into the soap solution and slowly start pushing gas into the solution. Several bubbles will typically form. At this point you want to move the syringe tip up to one of the bubbles next to the upper bubble surface and selectively inflate that bubble to a 1-2 inch diameter, giving a single nice-sized bubble. If you just put the syringe tip into the soap solution and push the gas in fairly quickly, you will make a "mass" of smaller bubbles. These can be ignited and usually will give a sharper bang, but it is harder to estimate the size as well as a single bubble.

Not so good:
Bubble cluster



Very Good:
Single large bubble

The students should practice at making the bubbles about the same size. Since the students will be comparing the loudness of the bubble explosion, it is reasonably important to try and make them the same size. After they have worked out the best stoichiometry for each combustible gas they can "play" with trying to make the biggest bubble for the biggest explosion. Students need to practice using the butane stick lighters to "master" the safety lock system.

Syringe Filling from Balloons: There will typically be 2 or 3 unknown combustible gases in different colored balloons. O_2 gas will be in the green (or blue) balloons. Students should flush out the syringe with about 5 mL of the first gas (usually O_2) they use when they are getting a gas mixture.

Be careful handling the balloon-valve assembly – some of the balloons may not be tied onto the valve and can be pulled off if you are not careful.

Except when testing a pure gas, you will want to mix various volume ratios of gasses (always O_2 and one of the combustible gases) and test the loudness of the resulting explosion. The data sheets provided contain a range of O_2:combustible gas ratios that should be tested. Not all of these need to be done. Better to test one ratio where there is more O_2 to combustible gas and one where there is less O_2 to probe which set of mixture ratios you should focus on.

To fill a syringe with the volume of the first gas you want open the valve by rotating it so it is parallel to the valve body. Then insert the plastic tip of the syringe into the middle of the rubber septum where a hole has been punched. Once the tip is inserted through the septum you can pull out the barrel of the syringe to get the volume of gas you want.

> **Note:** for the first gas you are getting (usually O_2) you should first withdraw about 5 mL of the gas, remove the syringe from the septum, then flush that gas out. Reinsert the tip of the syringe into the septum and fill the syringe with the proper volume of gas.

> **Important:** Never push any gas back into the balloon – *especially* when you have a mixture of gases. This can contaminate the balloons! If you pull too much of the first gas, remove the syringe and push out the extra into the atmosphere. If you pull too much of the second gas into the syringe you probably need to start over or note this on your experimental data sheet.

Withdraw the tip of the syringe and **close the balloon valve** (unless someone is waiting to use the balloon). Since the septum has a hole punched into it if you leave the balloon valve open the gas will slowly (or quickly) leak out through the septum.

Go to the other balloon (typically one containing a combustible gas) and repeat the above procedure to get the desired volume ratio. **Do not flush the syringe when filling with the second gas!**

You generally want to fill the syringe as full as possible, although for some volume ratios it may be easier to have less than 60 mL of the gas mixture. For example, for a 4:1 O_2/combustible gas mixture you would fill the syringe with 40 mL of O_2 and 10 mL of the combustible gas to give a total volume of only 50 ml. That is a little easier than using 48 mL of O_2 and 12 mL of combustible gas – also a 4:1 volume ratio.

Exploding the Bubble: Now that the syringe is filled with the combustible gas mixture (O_2 & combustible gas) you can return to your group and blow a consistently sized single bubble. *But before you start blowing a bubble, expel about 5 ml of gas from the syringe to clear out the tip section, which could be "rich" in the last gas you used.*

Blow a bubble, remove the syringe, and let one of the group partners ignite the bubble using the butane stick lighter.

> ***Note:*** It is important that students do <u>not</u> have the syringe near the bubble when igniting it! The syringe could explode if it is still inserted in the bubble or gets too near the butane lighter or bubble explosion. The person doing the butane lighter should ideally have the lighter lit and ready as the person finishes inflating the bubble with the syringe. If the "torch person" waits too long and tries to lite the lighter after the syringe student has withdrawn the syringe, it often takes several clicks to light the lighter and get a good flame and by that time the bubble may have burst. On the other hand, you don't want to light the bubble too soon – make sure the syringe has been withdrawn to a safe distance (foot or so).

If you wait too long to ignite the bubble it could break. But make sure the syringe has been fully withdrawn before igniting the bubble.

Stoichiometry Strategy: The data sheets have a lot of possible volume ratio combinations to test. If each group wants to try and identify each of the unknown gases (2 or 3) that could be a lot of experiments to do. Too much for a 45-50 min class, but OK for a 90 min lab block. On the other hand, if the students balance the reactions shown on the back of the data sheet they can more quacking home in on the best ratios of O_2 & combustible gases to speed up the identification of the unknown gases.
If the students in the class have not had any training in stoichiometry, you can give a short "lecture" on that topic using a reaction not shown on the data sheet (e.g., combustion of C_4H_{10}, butane).

There is an easy method for balancing hydrocarbon combustion rxns:

1. Stick with one equivalent of the hydrocarbon
2. # of CO_2's = # of carbons in hydrocarbon
3. # of H_2O's = ½ # of hydrogens in hydrocarbon
4. # of O_2's = # of CO_2's + ½ # of H_2O's (OK to be a fraction like 3.5)
5. Double check atom balance on each side of reaction
6. If you don't like fractional amounts of O_2, multiply entire equation by 2.