An Egg-splosive Demonstration

Description

A wide variety of containers has been used for illustrating the explosive power of a combustible gaseous mixture. These explosions are especially impressive when set up as time-delayed reactions -- with a flame burning over an upper orifice, then backfiring into the container. The following demonstration is the latest addition to this bevy of booms, but it utilizes one of nature's oldest containers--an egg shell.

Chemical Concepts

1. Hydrogen reacts with oxygen in a very quick and exothermic manner.
2. Contrary to popular belief, pure hydrogen, by itself, is not explosive. For hydrogen to explode, oxygen must also be present and at a sufficient concentration to react with the hydrogen.
3. Additional energy is often required to get reactant particles to collide hard enough to initiate a reaction; this extra energy is known as the activation energy.
4. As the temperature of a gaseous system increases, the pressure increases as well.

Safety

- The demonstrator should wear goggles during the entire demonstration, and a safety shield should be placed between the egg and the audience. Students must wear goggles if a shield is not used.
- Hydrogen is explosive. Make small amounts or release small amounts from a lecture bottle. If you use a hydrogen generator, stop the reaction as soon as the demonstration is complete. See Disposal.
- Place a fire extinguisher nearby.

Procedure

1. Fill the blown egg completely with hydrogen gas. (For instructions on blowing eggs, see the lab hints.) To do this, cover the top hole with a piece of electrician's tape, and introduce the hydrogen slowly through the bottom hole using the thin plastic tube extended upward almost to the top of the egg.

!!!Click here to See Movie.
From a hydrogen lecture bottle:
With the flow rate set at a minimum, charge the egg for 30-40 seconds to ensure a thorough flushing out of any air.
From a flask:
Place mossy zinc in the flask, add 100 mL of 1 M HCl, stopper securely with the thin plastic tube extending upward out of the stopper hole, and place the egg over the tube for 1-2 minutes.

2. Using the top of the soda bottle as a support, stand the egg in an upright position with the taped hole on top. [Remember to have a safety shield between the egg and the audience.]

   Then, to initiate the combustion reaction, simply remove the tape and hold a burning match or long lighter briefly to the top hole.
   !!!Click here to See Movie.

Stand back!

1. After a small initial "pop" sound, nothing appears to happen. Then, a short while later: "BOOM," and the egg is gone.

   If you have two eggs ready, ignite one in full light and the other in the dark. Compare the sound and light from the two explosions.
   !!!Click here to See Movie.
   !!!Click here to See Movie.
   !!!Click here to See Movie.

2. Each reaction mixture ignites slightly differently. Diffusion of air into the egg depends on the size of the upper and lower holes.

   !!!Click here to See Movie. Click |> or <| to step the slides forward or back. Slides are 1/60 sec apart.

3. If you are using a flask to generate the hydrogen, stop the production of hydrogen as described in the "Disposal" section.

   Methane Variation - The Flashing Egg
   Follow the same procedure described for the hydrogen egg, but make the holes each about 10 mm in diameter and charge the egg with methane from the gas jet (for only about 3-5 seconds!).

Questions

1. If hydrogen is combustible, then why does the egg not explode the instant the flame was brought near?
2. Describe the changes in the gas mixture inside the egg as the flame burns.
3. What eventually causes the egg to explode?

4. The egg does not constitute a closed system. So why does it explode?
5. Would this demonstration have worked the same with any combustible gas? Explain.

Handout Makeup

Name ____________________________ Class _______

Teacher ___________________________

BeckerDemos 002 An Egg-splosive Demonstration

1. Watch the movies. Describe the reaction in detail.
2. Sketch the egg and the reaction after the flame first ignites.
3. Note any other observations.
4. Answer the questions.

Curriculum-

Use when discussing energy of reaction, rates of reaction, or oxidation reduction. When discussing reaction rates, a comparison of the hydrogen and methane egg-splosions is interesting.

Activity-

- Demonstration - Teacher Only
- This activity is best done as a demonstration, especially around Easter time! Students may even bring in blown Easter eggs after Easter. Note the hole size is critical.

Safety-

- The demonstrator should wear goggles during the entire demonstration, and a safety shield should be placed between the egg and the audience. Students must wear goggles if a shield is not used. Flying egg shell can damage eyes.
- Use care with the hydrogen and methane. Both are explosive. Use only enough to flush the egg.
- Use a hood to fill the egg if possible.

Time-

Teacher Preparation: 10 minutes (the day before the activity)

Class Time: 5-10 minutes

Materials-

  - a lecture bottle of hydrogen

    or
  - 20 g mossy zinc

    - 100 mL 1.0 M HCl (1 liter -- Add 83 mL of 12 M HCl, hydrochloric acid solution to approximately 550 mL of water. After the solution equilibrates, dilute to 1000 mL with water.)
- 250-mL flask with one-holed stopper to fit
- 2-3 eggs, any size
- an ice pick or a sharp nail
- 10-15 cm of wire
- a piece of electrician's tape
- the upper portion of a plastic 2-L soda bottle, to serve as a small base for the egg
- 1 thin, plastic tube (such as the stem of a thin-stem plastic pipet) (OD < 3 mm)
- safety shield -- For a normal chicken egg, a 2-L soda bottle cut vertically to form a semicircular shield may suffice.
- a butane lighter, preferably with extended nozzle (such as the Scripto Aim 'n Flame® Torch lighter -- widely available in grocery stores for $3.00 - $4.00)

Disposal-

- Transfer the HCl flask to a hood immediately after use. Decant the HCl into a beaker. Rinse the Zn with water and decant the water to stop the production of hydrogen.
- The Zn may be used again. The HCl should be neutralized with $NaHCO_3$ and flushed down the sink.

Lab Hints-

Blow several eggs because you may have a dud or two. Sometimes the eggs have small cracks that are difficult to see but may break open during the filling process.

1. 1Wash the egg thoroughly. Then, with the ice pick or nail, gently tap a small hole (2-3 mm in diam.) in the top (narrower end) of the egg and a slightly larger hole (3-4 mm in diam.) in the bottom.

   !!!Click here to See Movie.
   !!!Click here to See Movie.
   Insert the wire and stir up the yolk. Over a bowl, blow into the small hole to force the egg's contents out through the larger hole. This may take some doing!
   !!!Click here to See Movie.

2. Rinse out the inside several times, and allow the egg to dry overnight at room temperature or for 30-40 minutes in a warm (100ºC) oven.
3. Wrap enough tape around the end of the thin plastic tube to fit securely in the rubber delivery hose of the hydrogen lecture bottle. If a lecture bottle of hydrogen is not available, then wrap enough tape around the end of the thin plastic tube (a thin-stem plastic pipet stem works well) so that it fits securely in the one-holed rubber stopper.

   Trouble shooting: If the egg blows up prematurely (the instant the flame is brought near), it indicates that a combustible mixture already exists in the egg. This may be the result of insufficient flushing. It is important to flush out as much air as possible. Make sure that the delivery tube extends to the very top of the egg and that you allow sufficient time for filling. Also, once the egg is filled with hydrogen, transfer it to the explosion shield, remove the tape and light it all within a relatively short period of time. Any delays will allow hydrogen to leak out and air to leak in.
4. **Methane Variation**

   Follow the same procedure described for the hydrogen egg, but make each hole about 10 mm in diameter.

Observations-

The initial pop is most likely caused by a small portion of the hydrogen leaking out, mixing with the air immediately above the hole and forming a minute combustible mixture there. Then, as more hydrogen gas slowly escapes through the top hole, it continues to react with the oxygen in the air and burns with an essentially invisible and silent flame. At the same time, oxygen-containing air is being drawn up into the egg through the bottom hole and mixing with the remaining hydrogen there. When enough air has entered to form a combustible mixture inside the egg, the flame back-fires down through the hole and ignites the mixture. Since the reaction is very exothermic, and since the holes in the egg are not large enough to accommodate the rapid expansion of the gases, the pressure inside the egg increases rapidly and explodes it into several small pieces.

The time-delay between the initial lighting of the egg and the subsequent explosion can vary quite significantly, lasting anywhere from a fraction of a second up to 30 or 40 seconds depending on the size of the egg, the size of the two holes and the extent to which the air inside the egg was effectively flushed out by the hydrogen.

Methane Variation

When the egg described above is charged with methane rather than hydrogen, the demonstration fails, for the flame burns out almost immediately, long before a combustible methane/oxygen mixture is reached. This appears to be a result of the small hole size, with the methane unable to leak upward at a rate sufficient for sustaining a flame above the egg. In order for a methane flame to sustain itself, the holes must be enlarged substantially. When this is done, the demonstration works but with a noticeably different outcome.

Unlike hydrogen, the methane burns quite visibly, starting off bright orange and 15-20 cm tall and diminishing to a small blue flame as the methane concentration inside the egg decreases. When the flame appears to be completely extinguished, the combustion reaction back-fires into the egg, similar to the back-firing for hydrogen. However, since the holes in the egg are so much larger, rather than an explosion, a soft "pfft" sound is produced and the entire egg lights up with a quick, pale-blue flash. Although perhaps somewhat less dramatic than the hydrogen egg, at least the methane egg is reusable!

Answers-

Q1. If hydrogen is combustible, then why does the egg not explode the instant the flame was brought near?
A1. Combustible means "reacts quickly with oxygen." Since there is virtually no oxygen in the egg initially, there is no way for the hydrogen inside to ignite.
Q2. Describe the changes in the gas mixture inside the egg as the flame burns.
A2. As hydrogen gas slowly escapes through the top hole, it continues to react with the oxygen in the air. The hydrogen in the egg is depleted by the reaction, thus its concentration inside the egg decreases. Also, as the hydrogen escapes out the top, air is drawn into the egg through the bottom hole. The concentration of oxygen therefore increases . Turbulence within the egg mixes the gases.
Q3. What eventually causes the egg to explode?
A3. When enough oxygen has entered the egg and mixed with the remaining hydrogen to constitute a combustible mixture, the flame can backfire through the hole and cause a rapid and powerful combustion inside the egg.
Q4. The egg does not constitute a closed system. So why does it explode?
A4. The exothermic reaction heats the gases inside the egg and causes a quick increase in pressure. The reaction is so fast and the holes in the egg are so small, that there is not sufficient time for the pressure to be released, so it builds up and quickly surpasses the threshold of the egg shell.

Q5. Would this demonstration have worked the same with any combustible gas? Explain.
A5. The demonstration would not have worked as well with other gases. The combustible gas must be less dense than air so that it would leak upward. It must be able to diffuse quickly through the hole, so that the flame on top can be maintained long enough to allow a combustible mixture to form inside the egg. And it must be a gas that burns quickly to cause the rapid increase in pressure responsible for the explosion.

Key Words 1-

gas, heat of reaction, explosion, rate of reaction, oxidation, reduction,activation energy