10.7 The [Chemiluminescent]* Ammonia Fountain

Subjects: Properties of gases, solubility of gases, pressure, chemiluminescence

Description: A small amount of water is injected into a sealed, inverted round bottom flask that is connected by tubing to two reservoirs below. Moments later, the liquid from the reservoirs flows up into the flask, creating a fountain effect. As the two liquids mix, they begin to emit a blue chemiluminescent glow that persists for 1 to 2 minutes.

***Note:** Chemiluminescence is optional and can be performed as a separate demo. If only performing the ammonia fountain, you need only one reservoir with water and phenolphthalein. As the water is pushed into the flask, it becomes pink due to the basic nature of the ammonia.

Materials:

For ammonia production	**For Fountain**
1L Erlenmeyer flask (use the flask on the prep shelf) One-holed stopper with bent glass tubing and flexible tubing pH paper (for testing effluent) 10 g Sodium hydroxide 10 g Ammonium chloride 2L Round bottom flask and 2-holed stopper	2 L Round bottom flask 1 or 2 500 mL beakers or flasks (on prep shelf or in drawer) Y-tubing (for chemiluminescence) 2-holed rubber stopper with straight tubing Medicine dropper Ring stand, clamps, and ring with clamp (on shelf above center bench) Water, phenolphthalein For Chemiluminescence: 2 g anhydrous sodium carbonate 1.5 L distilled water 0.1 g luminol (in refrigerator) 12 g sodium bicarbonate 0.25 g ammonium carbonate monohydrate 0.2 g copper(II)sulfate pentahydrate 25 mL 3% Hydrogen peroxide

Set-up of Apparatus: (immediately prior to demo)

1. First set up the apparatus by inverting the round bottom flask and attaching it to the ring stand using the clamps. Make sure the flask is dry. Stopper the flask and attach the Y tubing. Adjust the height so that the Y tubing extends to the bottom of the beakers or flasks. The RB flask will need to be almost at the top of the ring stand.

Once everything is adjusted to the proper height, remove the flask and tubing and move it to the hood for the ammonia generation.
2. In the hood, assemble the materials for producing the ammonia, including the 2-liter RB flask and the stopper. Prior to generating the gas, fill the medicine dropper with water and insert it into the second hole of the stopper. Be sure there is no excess water on the surfaces of the stopper or the medicine dropper.
3. Add the ammonium chloride and sodium hydroxide to the Erlenmeyer flask.
4. Add approximately 10 mL of water and stopper the flask. Swirl to mix. The end of the tubing should extend into the two liter round bottom flask. Hold the flask inverted.
5. As ammonia is generated it collects in the two liter flask, displacing the air in the flask.
6. Once the gas generator has slowed down, wet a piece of pH paper and place it at the opening of the flask to check that the flask is filled with ammonia vapor.
7. Immediately stopper the flask with the two-holed stopper. The glass tube should extend to within 10 cm of the bottom of the inverted 2-liter flask.
9. Place the 2 liter flask back on the ring stand, and reattach the Y tubing.

Solutions prep:
For solution A:
1. Dissolve 2.0 g of sodium carbonate in 250 mL of distilled water in one 500 mL beaker or flask.
2. Add 0.1 g of luminol and stir to dissolve.
3. Add 12.0 g of sodium bicarbonate, 0.25 g of ammonium carbonate monohydrate, and 0.2 gram of copper (II) sulfate pentahydrate.
4. Stir until all the solid dissolves. Dilute to a final volume of 500 mL.

For solution B:
1. Dilute 25 mL of 3% hydrogen peroxide to 500 mL of distilled water in the second 500 ml beaker or flask.

For Ammonia Fountain only:
1. Add water and phenolphthalein to a 500 mL beaker or flask

Place the apparatus and solutions on a cart and wheel it to the lecture hall.

Procedure:
1. Dim the lights.
2. Squirt the water in the bulb into the flask. After a few moments, the solutions in the reservoir(s) below will start to rise slowly, then increasing in speed. The solutions will rise and spill into the flask, creating a fountain effect. As the solutions mix, they emit a chemiluminescent blue glow that persists for a couple of minutes.

Discussion:

Fountain Effect:

Ammonia is one of the most water-soluble gases known. The volume of ammonia that will dissolve in water at 0° C and a partial pressure of 1 atm is 1130 L. The reason for this high solubility is the fact that ammonia reacts with water. Ammonia dissolves in water producing a solution containing ammonium and hydroxide ions in the following reaction:

$NH_3(aq) + H_2O \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

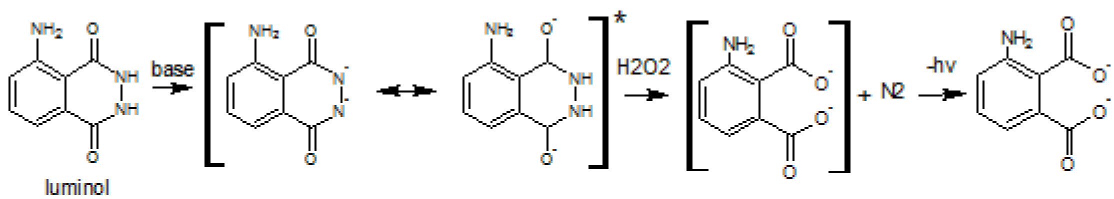
After the introduction of water into the top flask a small amount of ammonia dissolves in the water, creating a small partial vacuum. The difference in pressure between the flask and the atmosphere causes fluid in the reservoir to be pushed up into the flask. Once the solutions in the reservoir enter the flask and more ammonia dissolves into solution, the rate of the solutions flowing up increases, creating a fountain effect in the flask.

Chemiluminescent effect:

One of the most well-known examples of chemiluminescence is that of luminol (3-aminophthalhydrazide or 5-amino-2,3-diydrophthalazine-1,4-dione). The bright blue emission produced by chemiluminescent reactions of luminol is readily visible in a darkened room.

The reaction can be carried out in protic or aprotic solvents. In this demo, the reaction is carried out in water, a protic solvent. This requires a strong base, peroxide, and a catalyst such as iron (II) or copper (II). In this case the catalyst is the copper species. The wavelength of maximum emission is 425 nm.

The emitting species has been identified as a form of the product aminophthalate ion. The reaction mechanism is believed to take place as shown below:



The species required to initiate the oxidation of luminol in aqueous media is the superoxide radical anion, O2-. This species is formed in aqueous media by the decomposition of hydrogen peroxide. In highly alkaline aqueous systems, this decomposotion is catalyzed by the oxidation activators, such as the copper II species or hexacyanoferrate ion. The transition metal complex ions may also be involved in an electron-transfer step in the oxidation of luminol.

More about the actual mechanism of the reaction can be found in Shakhashiri[3].

Safety:
Ammonia gas is extremely irritating to the eyes, mucous membranes and respiratory system and is toxic if inhaled. It can also cause burns to the skin. Wear proper protective equipment and avoid inhalation. Sodium hydroxide is caustic and can cause burns to the skin. Only a round bottom flask should be used as the upper flask due to the pressures created.
Copper compounds are harmful if taken internally, and dust can irritate mucous membranes.

Disposal: Appropriate aqueous waste container.

References:
1. L. Summerlin, C. Borgford, J. Ealy; *Chemical Demonstrations: A Sourcebook for Teachers*; 1987; Volume 2; P.89

2. B.Z. Shakhashiri. *Chemical Demonstrations: A Handbook for Teachers of Chemistry*; Wisconsin; 1985; Volume 2; p. 205-210, Procedure A

3. B.Z. Shakhashiri. *Chemical Demonstrations: A Handbook for Teachers of Chemistry*; Wisconsin; 1983; Volume 1; p. 156-167