CheMagic Demonstration Notes©

Carbon Dioxide Hydration

Materials

800-mL fleaker; fleaker top with a drilled hole that allows a snug fit for a #1 rubber stopper; #1 rubber stopper; butane grill lighter

NOTE: Fleakers are hard to come by these days. A 1000-mL Erlenmeyer flask can be substituted for the fleaker. The #9 or #10 stopper for the Erlenmeyer is sufficiently large for drilling a hole for a #1 stopper. The Erlenmeyer does provide more of a problem for tilting the flask while the grill lighter is lit, however.

Chemicals

phenolphthalein solution (1% w/v) [e.g. 1 g phenolphthalein in 100 mL ethanol solution]; potassium hydroxide solution (2 M) [e.g. 28 g KOH in 250 mL solution]; DI water

Abstract

To 350 ml of water in the 800-mL fleaker, add 1 mL of 1% phenolphthalein solution and 1 drop of 2 M KOH. Place the specially drilled fleaker top on the fleaker. See the video of this demonstration to check this set-up.

Tilt the fleaker and insert the butane lighter in the hole drilled in the fleaker top. Using the lighter trigger, ignite the butane flame. If the base of the butane lighter is pressed snuggly against the hole in the top of the fleaker, the flame inside the flask will self extinguish.

After the flame is extinguished, withdraw the lighter and place the #1 rubber stopper in the hole in the fleaker. Make sure the system is tightly closed and give the fleaker a good shake. The red phenolphthalein color will disappear as the carbonic acid (from CO_2 hydration) neutralizes the potassium hydroxide, but the rate of disappearance is much slower than the rate of disappearance with SO_2 produced sulfurous acid in the acidic oxide demonstration (q.v.)

Obligatory but Very Important Note

Please check the demonstration video for details on the above abstract. Are there possible hazards and risks in this demonstration? Yes, absolutely. The fleaker could crack during ignition of the grill lighter. The demonstration involves fire that could get out of hand. Butane lighters have been known to explode. We have not experienced specific problems in our use of the demonstration, but potential problems are there. This video demonstration manual is distributed to chemists and chemistry teachers, and the assumption is made that professionals using the manual are knowledgeable about materials, chemicals, demonstration procedure, and demonstration risks. If there is any doubt about risk, then please show your students the video rather than doing the demonstration.

Demonstration Note

This demonstration is part of our *light hearted* approach to some foundation chemical reactions on the planet that we call "Earth:

Chemistry Planet Earth

- Planet Earth has stuff.
- There is metal stuff and there is non-metal stuff – also some borderline stuff.
- There is quite a bit of non-metal stuff called oxygen which causes other stuff to burn.
- Stuff burns.
- There is quite a bit of stuff called hydrogen which burns to form water.
- Metal stuff that burns produces other stuff that tends to react with water to produce chemical bases.
- Non-metal stuff the burns produces other stuff that tends to react with water to produce chemical acids.
- Most stuff is already all burned up.

The demonstration illustrates the following general reaction sequence:

General	**Butane**
Non-metal + $O_2 \rightarrow$ Non-metal Oxide	$2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$
Non-metal Oxide + $H_2O \rightarrow$ Acid	$CO_2 + H_2O \rightarrow H_2CO_3$

In the case of butane combustion, the carbon in the butane forms carbon dioxide. The carbon dioxide then reacts with water to produce carbonic acid (H_2CO_3). This latter hydration of CO_2 is noticeably slower than the SO_2 hydration in the Acidic Oxide demonstration (q.v.), and hence the disappearance of the red basic phenolphthalein color is much slower. The slowness of carbon dioxide hydration is of biological importance.

The hydration of carbon dioxide has been reviewed in the Journal of Chemical Education [Kern, David M., *J.Chem.Educ.*, **37**, 14(1960)]. A clock experiment that makes use of the relatively slow rate of carbon dioxide hydration has also been described [Jones, P.; Haggett, Max L.; Longridge, Jethro L., *J.Chem.Educ.*, **41**, 610(1964)]. Additionally, the Journal has reported a laboratory experiment that investigates the catalytic action of carbonic anhydrase [Spyridis, Greg T.; Meany, J. E.; Pocker, Y., *J.Chem.Educ.*, **62**, 1124(1985)].

A rather more complex demonstration of the acid rain component of this demonstration has been published in the Journal of Chemical education [Driscoll, Jerry A., *J.Chem.Educ.*, **74**, 1424(1997)]. An interesting periodic table approach to presenting the chemistry of acidic and basic oxides is also available in this journal [Rich, Ronald L., *J.Chem.Educ.*, **62**, 44(1985)]. Finally, a general discussion of acidic, basic, and amphoteric oxides is suggested as relevant background for this demonstration [Smith, Derek W., *J.Chem.Educ.*, **64**, 480(1987)].

The chemical demonstration described above is suggested for use by chemical educators and other chemical professionals interested in the instructional use of chemical magic. It is assumed that qualified chemical professionals using this manual are familiar with the properties of the chemicals and with the characteristics of the materials involved in all of the demonstrations. Any attempts to repeat the demonstrations in this manual MUST be carried out under the supervision of a qualified chemical professional.