Zinc Pyrotechnics

An Exothermic Redox Eruption

Introduction

A spectacular "fireworks" display is initiated by adding just two drops of water to a mixture of dry chemicals.

Chemical Concepts

- Oxidation–reduction reactions
- Decomposition reactions
- Autocatalysis
- Catalysis (optional—see Tip section)

Materials

Ammonium chloride, NH_4Cl, 1 g
Ammonium nitrate, NH_4NO_3, 8 g
Zinc dust, Zn, 8 g
Water, distilled, 1 mL
Beaker, Pyrex®, 50-mL
Ceramic fiber square or heat-resistant surface
Fume hood
Medicine dropper or Beral pipet
Stirring rod

Safety Precautions

Ammonium nitrate is a strong oxidizer; may explode if heated under confinement or at temperatures of 250 °C; toxic by ingestion and inhalation; skin, eye, and respiratory irritant. Zinc dust can be a dangerous fire risk; may form explosive mixture with air. If allowed to get damp in a confined bottle, heat will be generated and the mixture may possibly ignite. Ammonium chloride is toxic by ingestion. Zinc oxide fumes, one of the products of the reaction, can be toxic and severely irritating.

Do not premix the ingredients before the demonstration. They can react prematurely and, if in a closed container, explode violently.

This reaction should only be done in an operating fume hood or possibly out-of-doors due to amount of smoke produced. This reaction also produces a great deal of heat so it is imperative that an insulating material such as the ceramic fiber square be placed under the beaker. Do not scale this reaction up. The demonstrator should wear chemical splash goggles, a chemical-resistant apron, and chemical-resistant gloves. Students should wear chemical splash goggles. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Remove all combustible materials from the fume hood. Place the 50-mL Pyrex beaker on a ceramic fiber square or other heat-resistant surface inside a fume hood.
2. Add 8 g of ammonium nitrate, 8 g of zinc dust, and 1 g of ammonium chloride to the beaker; mix with a dry stirring rod.
3. Using the medicine dropper or a Beral pipet, add two drops of distilled water to the beaker and quickly lower the hood shield. Do not add more than two drops.
4. Observe the reaction and "fireworks!"

Disposal

The solid products of this reaction may be disposed of in a landfill according to Flinn Suggested Disposal Method #26a.

Tip

- This demo can be modified to provide a dramatic example of catalysis. Prepare two 50-mL Pyrex beakers with the ammonium nitrate and zinc dust, as described, but only include ammonium chloride in one of the beakers. Add the

Publication No. 859
032417

two drops of water first to the beaker without ammonium chloride. It will produce smoke and vapor, but will probably not produce flame. After the reaction is complete, add two drops of water to the second beaker. The reaction will proceed much more quickly and will produce smoke, sparks, and flames—the "eruption."

Discussion

The mechanism of this reaction is complex. It is believed that the heat produced by the addition of water to the zinc dust melts the ammonium nitrate. Once melted, ammonium nitrate volatilizes, producing N_2O and H_2O. This reaction is catalyzed by chloride ions:

$$NH_4NO_3(s) \xrightarrow{\text{heat}} NH_4NO_3(l) \xrightarrow{[Cl^-]} N_2O(g) + H_2O(g)$$

The energy change for the volatilization of ammonium nitrate to nitrous oxide and water is reported to be –23 kJ/mol. As the volatilization proceeds, this heat produced causes the zinc to dissolve in the molten ammonium nitrate. This leads to the rapid oxidation of the zinc, possibly according to the reaction:

$$Zn(s) + NH_4NO_3(s) \rightarrow N_2(g) + ZnO(s) + 2H_2O(g)$$

The energy change for this reaction has been calculated to be –466.5 kJ/mol. This tremendous amount of energy produced causes the dispersal of zinc oxide as a white cloud and yellow/white particulate matter.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium

Content Standards: Grades 5–8
- Content Standard B: Physical Science, properties and changes of properties in matter
- ßContent Standard B: Physical Science, structure of atoms, structure and properties of matter

References

Cotton, F. A. and Wilkinson, G. *Advanced Inorganic Chemistry: A Comprehensive Text;* John Wiley and Sons: New York, 1980; p 417.

Shakhashiri, B. Z. *Chemical Demonstrations: A Handbook for Teachers in Chemistry;* University of Wisconsin: Madison, WI; 1989; Vol. 1, pp 51–52.

Materials for *Zinc Pyrotechnics* are available from Flinn Scientific, Inc.

Catalog No.	Description
Z0005	Zinc Dust, 500 g
A0241	Ammonium Nitrate, Crystal, Reagent, 100 g
A0266	Ammonium Chloride Granular/Lump, Reagent, 100 g
AP1245	Ceramic Fiber Squares, 6'' 6'' × 1⁄8'', pkg. of 12
AP9117	Zinc Pyrotechnics—Chemical Demonstration Kit

Consult the Flinn Scientific website for current prices.