That Remarkable Kind of Action

The Exciting Nature of Chemistry

Introduction

Ira Remsen's memoir of his discovery of the properties of nitric acid has become an enduring symbol of the wonders of chemistry. Teachers love to retell the story as they recreate the demonstration that inspired the young Remsen "to learn more about that remarkable kind of action." The setup in this demonstration is one that Ron Perkins showed at a Sacred Heart University workshop.

Concepts

- Chemical reactions
- Oxidation-reduction

Materials

Copper penny (pre-1982)

Nitric acid, concentrated, HNO_3, 15.8 M

Phenolphthalein indicator solution, 1%, a few drops

Sodium hydroxide solution, 0.1 M

Steel wool

Water, tap, 300 mL

Beaker, 100-mL

Florence flask, 500- or 1000-mL

Graduated cylinders, 25- and 500-mL

Medicine dropper

Plastic tubing, 50-cm length (or glass tubing connected with plastic tubing)

Rubber stopper, one-hole, to fit flask

Scissors, student or iron nail

Stirring rod

Support stand and clamp

Safety Precautions

Nitric acid is corrosive to eyes, skin, and other tissue; strong oxidant; toxic by inhalation; avoid contact with readily oxidized substances. Sodium hydroxide solutions are corrosive to eyes, skin, and other tissue. Phenolphthalein indicator solution is an alcohol-based solution and therefore flammable. Copper(II) nitrate solution is toxic. Nitrogen dioxide produced in the reaction is an irritant and toxic by inhalation. This demonstration must be done in a hood or well-ventilated area. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Set up the flask, stopper, tubing and 500-mL graduated cylinder as shown in Figure 1, placing approximately 300 mL of tap water in the cylinder.
2. Add a few drops of 1% phenolphthalein solution to the cylinder and stir.
3. Add 0.1 M sodium hydroxide solution drop-wise with continuous stirring until the solution in the cylinder remains pink.

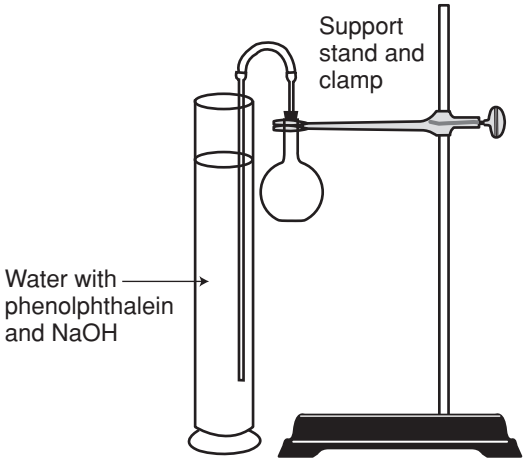

Figure 1.

Procedure

1. Have the students sketch the set-up into their notebooks.
2. Then, after a little introduction as to who Ira Remsen was (see *Discussion*), read the passage from his journal found at the end of the procedure. The inserted numbers correspond to steps in the procedure that can be completed at those particular times.
3. Hold up the penny to be used, perhaps point out that it needs to be a pre-1982 penny, for that was the year the US mint changed their recipe

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for making pennies—from mostly copper then to mostly zinc now.

4. With goggles deliberately in place, hold up a stock bottle of nitric acid.
5. Read the precautions on the label, to enlighten the students as to some of the "peculiarities" of nitric acid!
6. Begin the demonstration; explain that for safety reasons you will be conducting the same reaction in a little more confined a space. Open the flask, slide the penny in (dropping it in could crack the bottom of the flask), and pour approximately 20 mL of the acid into the flask. Quickly re-stopper the flask securely, making sure that the tubing in the cylinder extends down into the water. The reaction begins immediately, with a soluble reddish-brown gas (NO_2) being produced with a slight rattling noise as the bubbles bounce the penny around against the bottom of the flask. The bubbles also begin inside the cylinder, as the NO_2 displaces the air out of the flask. If the set-up is on a steady cart, you may consider wheeling it around to give students a closer view of the process. The reaction continues for about 5–7 minutes, with the flask eventually becoming so dark (especially at the bottom) that it is nearly opaque. You may also want to point out that the flask has become somewhat warm on the bottom. Eventually the bubbling in the cylinder peters out, even though the penny is still bubbling away in the flask (hmmm...). Note that the solution in the cylinder has changed from pink to colorless. Then the bubbling in the flask peters out as well. But the demonstration is not over—back to the reading.
7. Point out that all colored gases are poisonous. That in itself is a lesson worth remembering!
8. If the timing is right, you should not have long to wait for the grand finale. Look at the water level inside the tubing. When the bubbling first stopped, the water level was obviously at the very bottom of the tube, but as cooling of the hot gas and some dissolving of the very soluble NO_2 begin, the pressure inside the flask begins to decrease, and so the water gets "sucked" up (actually pushed up by the greater pressure in the room) back into the flask. The first bit of water that trickles in allows quite a bit more of the NO_2 to dissolve into it, thus causing an even greater decrease in pressure and hence an even faster transfer rate of water into the flask. Within 10–15 seconds, the graduated cylinder runs dry (with a thirst-quenching slurping sound), and the flask is about one-fourth filled with a beautiful blue liquid... and virtually no brown gas left at all.

Narration

"While reading a textbook of chemistry, I came upon the statement, 'nitric acid acts upon copper.' I was getting tired of reading such absurd stuff, and I was determined to see what this meant. Copper was more or less familiar to me, for copper cents were then in use. *(3)* I had seen a bottle marked 'nitric acid' *(4)* on a table in the doctor's office where I was then 'doing time.' I did not know its peculiarities, but the spirit of adventure was upon me. *(5)* Having nitric acid and copper, I had only to learn what the word 'act upon' meant. The statement 'nitric acid acts upon copper' would be something more than mere words. In the interest of knowledge, I was even willing to sacrifice one of the few copper cents then in my possession. I put one of them on the table, opened the bottle marked nitric acid, poured some of the liquid on the copper and prepared to make an observation. *(6)* But what was this wonderful thing which I beheld. The cent was already changed, and it was no small change either! A green-blue liquid foamed and fumed over the cent and over the table. The air in the neighborhood of the performance became colored dark red. A great colored cloud arose. This was disagreeable and suffocating. *(7)* How should I stop this? I tried to get rid of the objectionable mess by picking it up and throwing it out the window. I learned another fact. Nitric acid not only acts upon copper, it acts upon fingers. The pain led to another unpremeditated experiment. I drew my fingers across my trousers and another fact was discovered. Nitric acid acts upon trousers. Taking everything into consideration, that was the most impressive experiment, and, relatively, probably the most costly experiment I have ever performed. It was a revelation to me. It resulted in a desire on my part to want to learn more about that remarkable kind of action. Plainly, the only way to learn about it was to see its results, to experiment, to work in a laboratory." *(8)*

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The product in the demonstration is an acidic solution of copper(II) nitrate. The solution may be neutralized with base and disposed of with plenty of excess water according to Flinn Suggested Disposal Method #24b. *Note:* Many states regulate or limit the amount of copper(II) salts that may be disposed of down the drain with excess water. Always check with your local or state agencies before disposing of any substance down the drain. Please call or write Flinn Scientific to request a free copy of "Precipitation and Disposal of Copper(II) Solutions", Publication No. 10870.

Tips

- Call a student up to take a final observation on the condition of the penny. Often they are amazed to find it completely gone. Where did the penny go? Can we get it back? Where did the brown gas come from and where did it go? And where did the blue liquid come from? The demonstration certainly raises many good questions. It is best to let the students try to answer them on their own, just based on what they observed.
- For an extension to this activity, remove the flask from the clamp, swirl the contents to dissolve any remaining NO_2 gas, remove the stopper and pour out about 60 mL of the blue solution into a 100-mL beaker. Buff the blades of steel scissors (or an iron wire or nail) with steel wool, place them in the solution for 10–20 seconds. They should come out with a beautiful copper coating over the portion that was submerged. It is truly amazing to consider that ten minutes earlier those same atoms of copper were locked inside the penny and now, here they are, coating this pair of scissors.

Discussion

Ira Remsen (1846–1927) was an influential American chemist in the 19th and early 20th centuries. Trained as a physician in New York City, Remsen abandoned the practice of medicine soon after receiving his degree, choosing instead to pursue a passion for chemistry. After receiving a doctorate in organic chemistry in Germany in 1870, Ira Remsen returned to the United States, where he founded the chemistry department at Johns Hopkins University. He later served as president of the university as well. Credited with the co-discovery of the artificial sweetener saccharin, Ira Remsen left behind a rich legacy of research in organic chemistry. Remsen felt that his most important contribution, however, was not to research but to education, "to promote the study of pure science, to develop a scientific habit of mind in students, and to train them to become investigators." Given his devotion to chemistry education, Ira Remsen would be pleased to know that one story in particular from his lifetime of interest in chemistry has been passed down from generation to generation.

The copper penny reacts with the nitric acid to produce nitrogen (II) oxide.

$$3Cu(s) + 2NO_3^-(aq) + 8H^+(aq) \rightarrow 3Cu^{2+}(aq) + 4H_2O(l) + 2NO(g)$$

The nitrogen(II) oxide quickly reacts with oxygen to form nitrogen dioxide, a red-brown gas.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

As the NO_2 gas pressure increases, it bubbles through the basic (pink) solution in the cylinder. Nitrogen dioxide is very soluble in water. As it dissolves, it reacts with the water to form nitric acid, which lowers the pH of the solution as it is formed.

$$2NO_2(g) + H_2O(aq) \rightarrow 2HNO_3(aq)$$

As the solution in the cylinder changes from basic to acidic, the color of the phenolphthalein indicator changes from pink to colorless.

When the copper pennies are completely dissolved, the reaction stops. As the Florence flask cools, the pressure inside the flask decreases. This lower pressure draws the solution from the cylinder into the Florence flask. As the liquid flows into the Florence flask, it dilutes the copper(II) nitrate solution that was formed by the initial reaction of copper with nitric acid. The Cu^{2+} ions color this solution a bright blue.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *That Remarkable Kind of Action* activity, presented by Bob Becker, is available in *The Exciting Nature of Chemistry*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *That Remarkable Kind of Action* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in *The Two-Cent Colorful—Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP8989	The Two-Cent Colorful Demonstration Kit
N0043	Nitric Acid, 15.8 M, 100 ML
S0149	Sodium Hydroxide Solution, 0.1 M, 500 mL
P0019	Phenolphthalein Indicator Solution, 1%, 100 mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.