Metallic Copper + Concentrated Nitric Acid

(aka three discoveries in a single day)

Materials:

Copper penny, 500 mL flask, ring stand 50 mL of conc. HNO_3, 1000 mL beaker, glass tubing.

Introduction:

A copper penny is exposed to concentrated nitric acid, the reaction is highly exothermic. A blue solution of Cu^{2+} ions and brown fumes of nitrogen dioxide are evolved.

You can amaze the class by flipping a very clean copper penny in front of them.

See 'The Remson Story' reproduced below.

The Remson Story:

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. I had seen a bottle marked nitric acid 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. Having nitric acid and copper, I had only to learn what the words "act upon" meant. The statement "nitric acid acts upon copper" would be more than mere words.

All was still. 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. 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. How should I stop this?

I tried to get rid of the objectionable mess by picking it up and throwing it out of the window. I learned another fact.

Nitric acid not only acts upon copper, but 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 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.

DEMOS

Procedure

Place a penny into 50 mL of conc. HNO_3 and stopper with a tube. The end of the tube is placed into a beaker of water covered with a wet cloth over the opening.

- copper penny (pre-1982) is added to the colorless HNO_3, the solution turns green and a large amount of red-brown gas is formed.
- The air being displaced by the gas formation can be seen bubbling through the water.
- The flask gets VERY hot. When enough gas is formed, it bubbles through the water (keep the liquid stirred so most of it will dissolve. The gas that makes it to the top is noxious.)

Later...

- The gas in the flask begins to cool and therefore contracts.
- Pressure in the flask decreases, the outside pressure forces water back toward the flask.
- The gas dissolves in the water. Eventually, the water rushes into the flask, the solution turns characteristic blue, and the brown gas disappears as it is dissolved.

The Chemistry

REDOX Reaction: between copper metal and conc. nitric acid (a strong oxidizing agent). Copper metal is oxidized to copper(II) ion while the nitrogen(V) in the nitrate ion is reduced to nitrogen(IV) in the nitrogen dioxide gas.

$$Cu(s) + 4\ H^+(aq) + 2\ NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2\ NO_2(g) + 2\ H_2O(l)$$

$$3\ Cu + 8\ HNO_3 \text{ --> } 3\ Cu(NO_3)_2 + 2\ NO + 4\ H_2O$$

Limiting Reagent: the reaction comes to an end when the last of the copper is used up. This makes the copper the yield limiting reagent.

Charles' Law: the exothermic reaction warms the gas, the gas expands. As it cools, the gas contracts.

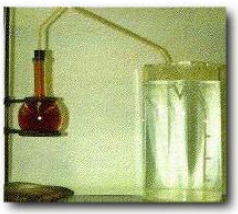
Nonmetal oxides are acid anhydrides (also link to acid rain): although the nitrogen dioxide gas is noxious and toxic, it dissolves readily in water and makes the solution acidic. This can be shown by adding a little indicator to the water and making the water slightly basic before the copper is added to the acid.

Air pressure: as the pressure in the flask is decreased as it cools, the outside pressure pushes the water up the tubing toward the flask. The nitrogen dioxide gas is not pulling the water in.

Descriptive chemistry--copper solutions are green and blue: the colored solutions come from complexes of copper(II) ion in solution. Aqueous copper ion is blue, $Cu(H_2O)_4^{2+}$ The green must be copper surrounded by nitrates(?)

Safety and Disposal

The solution is highly acidic. I pour it out into a large beaker or battery jar and add excess sodium carbonate. The carbon dioxide bubbles indicate neutralization and the resulting copper carbonate precipitate is filtered, placed in a baggie and thrown away. The neutralized filtrate can be disposed of as you would any simple salt solution. Procedures may vary from location to location.



$Cu + HNO_3$

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