A COLORFUL OXIDATION REDUCTION DEMONSTRATION

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INTRODUCTION

A description in Sienko and Plane (1) of color changes occurring in solutions containing vanadium in the +5 oxidation state as it is reduced stepwise to the +4, +3, and +2 states suggested the probability of a colorful and interesting demonstration. Only one such demonstration was found in chemical literature. This was by Peacocke (2), also written by Dutton (3). This demonstration called for dissolving 0.5 g of ammonium vanadate in 100 ml of water, acidulated with 7.5 ml of 6 N sulfuric acid. This was then reduced by use of 20 g of zinc amalgum, such as used in a Jones reductor. Reduction resulted in color changes from the yellow vanadate solution VO_2^+, to blue VO^{++}, to green V^{+3}, to violet V^{+2}. These oxidation states of vanadium were explained by the loss of the 2, 4s electrons in the case of V^{+2}, and then the additional loss of 1, 2, and finally all 3 of the 3d electrons for the other states.

EXPERIMENTAL

Various reducing agents were tested with the zinc amalgum and plain strips of analytical zinc proving to be the best, producing especially the best color effects. These two were about equally effective.

Several oxidizing agents were then used to see if the process could be reversed. Both nitric acid and hydrogen peroxide were found to be successful. Hydrogen peroxide, in about 3% solution, was the better one. By its use the process could be reversed, thus demonstrating oxidation as well as reduction, and the chemicals could be used over and over again in later demonstrations.

Other compounds of vanadium were then used. Vanadium pentoxide was successfully used though some difficulty was experienced in solubility. Considerable acidulation with H_2SO_4 was required to increase the solubility and this then interfered in later reactions. Vanadium tetrachloride proved to be superior even to the ammonium vanadate used by Peacocke in that it was readily soluble and a more concentrated solution could be obtained.

RESULTS

Dissolve 1 g of the brown liquid vanadium tetrachloride in 40 ml of water, acidulated with 10 ml of 6 N HCl. This produces a bright blue solution. Oxidize this V^{+4} (Probably containing VO^{++}, or $V(OH)_2^{++}$ ions) to the red-brown V^{+5} state, (ions variously described as VO^{+3}, $V(OH)_2^{+3}$, VO_2^+, and $V(OH)_4^+$) by use of 3% hydrogen peroxide (about 5 ml will be required). From this +5 state as a starting point reduce with either zinc amalgum or with plain strips of analytical zinc through the previously described states. Heating the solution speeds up the reaction. At near the boiling point the entire reduction process can be completed in about 5 minutes. Cool the solution and oxidize back to the starting point with hydrogen peroxide. With a little practice one can stop at any desired oxidation state. These stops may be made during the reduction by merely pulling out the zinc strips or by decanting in case the amalgum is used. During oxidation desired stops are made by the stepwise addition of the proper amounts of hydrogen peroxide. Starting with the solutions previously prepared the entire reduction and oxidation demonstration can be performed in about 20 minutes if heated to near the boiling point during the reduction.

The actual color changes observed are from red-brown, to green, to blue, to green, to violet. The first green color observed is believed by this writer to be due to a mixing of colors when part of the vanadium is in the +4 state while the rest is still in the +5 state. The solution stores best for later use in the +4 state.

BIBLIOGRAPHY

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