Mirror, Mirror, On the Bottle

Introduction

Mirrors, also known as looking glasses, have been known since ancient times. The earliest mirrors were made by polishing disks of a metal such as bronze. These simple mirrors did not last very long due to oxidation of the metal and abrasion from everyday use. In the middle ages, beautiful mirrors were made by backing glass with thin sheets of metal foil, usually silver. Mirrors produced in this manner were very expensive. In 1835, the German chemist Justus von Liebig (1803–1873) invented the silverying process used in this demonstration. This process, which is still used today in the manufacture of household mirrors, involves a variation of Tollens’ test. Most household mirrors are made with silver because light reflected from a silveryed mirror has a slight pink tinge to it, which enhances skin tones.

Tollens’ test is a qualitative test used by chemists to determine if an aldehyde functional group is present in a compound. Treatment of an aldehyde with a solution of silver nitrate in ammoniacal sodium hydroxide produces a silver mirror on a glass surface. This process does not require any electricity and is called “electroless plating.” In this experiment, silver metal is produced. Dextrose, a reducing sugar, is used to reduce silver ions in Tollens’ reagent to silver metal, which is then deposited on the inside of the test tube. The reactions involved in this activity are summarized below.

The atoms of most metallic elements lose electrons in the dissolving process. Silver, dissolved in nitric acid, loses one electron (its outermost one) and forms and ion, which is a charged particle. The resulting ion which has 47 p+ and 46 e−, carries a charge of +1, and is called a cation. The solution which you will use as a source of Ag+ ions is labeled AgNO3, and is actually a mixture of Ag+ cations and NO3− anions floating around together in a water solution, which is colorless and bears no resemblance to silver metal.

In this experiment, you will try to provide the Ag+ ions with a source of additional electrons, hoping to form silver metal in the process. In solution, Ag+ NO3− has an acidic pH. The potassium hydroxide (KOH) is added to increase the pH (basic) and make the Ag+ precipitate out as a solid mass of silver oxide (a dark brown precipitate).

\[
2\text{Ag}^+ (\text{NO}_3)^{-} + 2\text{KOH}^{-} \rightarrow \text{Ag}_2\text{O}^{-} (s) + 2\text{K}^+ (\text{NO}_3)^{-} + \text{H}_2\text{O}
\]

Ammonium hydroxide is added to create a complex Ag+ ions which are placed in solution to produce Tollens’ reagent. A complex ion is one that is composed of two or more ions surrounding and protecting the central ion.

\[
2\text{Ag}_2\text{O}^{-} + 4\text{NH}_4\text{OH} \rightarrow 2[\text{Ag(NH}_3)_2]^+ \text{OH}^{-} + 2\text{H}_2\text{O}
\]

The silver ammonia complex allows Ag+ ion to collect free electrons from the reducing sugar and reduce to silver metal.

\[
\text{R-CHO} + 2[\text{Ag(NH}_3)_2]^+ \text{OH}^{-} \rightarrow \text{R-COONH}_4 + 2\text{Ag} (s) + 3\text{NH}_3 + \text{H}_2\text{O}
\]

Aldehyde
The source of the electrons in this experiment will be a solution of dextrose which is a type of sugar.

![Aldehyde functional group]

**Concepts**
- Oxidation–reduction
- Reducing sugars
- Tollens’ test

**Materials**
- Ammonium hydroxide solution, NH₄OH, 15 M
- Dextrose solution, C₆H₁₂O₆, 0.25 M
- Nitric acid, HNO₃, 6 M (optional)
- Soda bottle, glass
- Silver nitrate solution, AgNO₃, 0.1 M
- Potassium hydroxide solution, KOH, 0.80 M

**Safety Precautions**
Potassium hydroxide solution is a corrosive liquid and is especially dangerous to the eyes. Silver nitrate solution is toxic by ingestion and will stain skin and clothing. The mixed solution in the flask may form a potentially explosive material if left standing and allowed to dry. Do NOT mix the solutions beforehand—add them together in the test tube and follow the instructor’s directions for disposing of the leftover solution immediately after use. Rinse with copious amounts of water. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the lab.

**Procedure**
1. Obtain a small bottle and cap. Place the bottle in warm water
   **************************** IN A BEAKER ****************************
2. Pour 15 mL of [0.1M AgNO₃] solution into a beaker
3. Add 1 drop of [15M NH₄OH] to the AgNO₃. If a brown color persists after stirring, add one more drop of NH₄OH and stir again. Keep adding one drop and stirring until the brown color disappears.
4. Add 10 mL of [0.80M KOH] If the brown color reappears, add 1 drop 15M NH₄OH and stir, repeating as necessary.
   **************************** IN THE BOTTLE ****************************
5. Empty the water from the bottle. Add [15 mL of 0.25M dextrose] solution. Add the contents of the beaker, cap the bottle, and shake the bottle continuously to cover the entire surface with a thin coat of liquid. Dump out the remaining solution, washing it down he drain with plenty of water. RINSE THE BOTTLE THOROUGHLY WITH COLD WATER!