EXPLORING GLASSES AND GLAZES IN THE HISTORY OF CHEMISTRY AND THE UNDERGRADUATE LABORATORY

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ABSTRACT

The purpose of this work was to make samples of glass, related to the craft of glassmaking in the History of Chemistry. Compositions suitable for preparation at temperatures of 850°C and 1350°C were developed and tested. At the higher temperature, it was possible to use a higher percentage of SiO_2 in preparing glass samples.

Keywords

Glassmaking, history of chemistry, colored glass

INTRODUCTION

During Fall 1998, History of Chemistry was offered at Augustana College. GJH chose glassmaking as one of his laboratory activities, and placed this in the context of History of Chemistry. This included laboratory work which began the present study.

HISTORICAL BACKGROUND AND METHODS

The basic techniques for making glass are extremely old, and in many ways it could be said that modern techniques and processes are simply refinements of the old techniques. It is believed that the earliest objects made of glass are Egyptian beads that date back as far as 3000-2500 B.C. "The earliest glass vessels, made in Egypt during the Dynasty (1500-1350 B.C.), were made by a method that was in essence an extension of the glazing process" (Kirk-Othmer 1966). Other glass vessels that were found are believed to be of Mesopotamian origin.

Sand, limestone, and soda were the key ingredients used in early glassmaking, These ingredients made glass easy to make and manipulate, and was generally referred to as "Lime Glass." This was the most common glass because the materials were easily obtained and it could be made by using lower temperature. The "Lime Glass" was also very stable and allowed for easy resoftening for the molding and shaping processes. The one thing to remember when making this glass though is that typically, the melting point of sand is 1580°C. That means that the more sand that is in the mixture, the higher the melting temperature will be.

The Romans added the ability to make colored glass. "They knew that specific colors could be achieved by adding particular metallic oxides to the raw materials" (Kirk-Othmer 1966). They learned that they could get a ruby red or green by adding copper, cobalt for blue, manganese for amethyst or purple, antimony for yellow, iron for green, brown, or black, and tin for an opaque white. The first small glassworks in America was made at Jamestown, Virginia, around 1609. Since then, rapid population growth and the increasing rate of urbanization has created a bigger need for glass. (Harrington, 1952).

Many different types of glass have become available over the years. Window glass is a soda-lime glass with a typical composition of73% SiO_2, 17% Na_2O (soda), 5% CaO (lime), 4% MgO, and 1% Al_2O_3. In the process of making Pyrex glass, the procedure is to use soda and borax to lower the softening point of the sand to about 800°C. Leaded glasses are made with litharge (PbO) and are typically made into fine glassware. Laminated glass is made by placing a sheet of plastic between two layers of glass. An example of this would be the glass used for the front windshields of vehicles. Toughened glass is regular glass made by cooling the glass rapidly. Some examples of this kind of glass may be the rear or side windows of vehicles and the shower doors in a home.

A Thermolyne Type 1400 Furnace was used to heat mixtures to 850°C. A Fisher High Temperature Furnace Model 472 was use for heating samples to 1300°C.

RESULTS AND DISCUSSION

In the present work, representative compositions of mixtures heated to prepare glass or glazes, modified from the literature to allow lower working temperatures, around 850∞C, are as follows. (Kirk-Othmer, 1966; Corning, 1997).

Colorless soda-lime glass: 55 % SiO_2, 45% Na_2CO_3.

Cobalt blue glass: 60 % SiO_2, 35 % Na_2CO_3, 5 %$CoCO_3$.

Typically such a mixture was heated to about 850°C for 1-2 days, and then cooled slowly.

The next stage of this work was to heat such mixtures to higher temperatures. The Fisher High Temperature Furnace Model 472 tube furnace acquired recently can safely achieve 1500°C. So far this has been used around 1350°C, which has made it possible to go to higher percentages of SiO_2, in the direction more nearly typical of commercial glasses. The composition range of the best looking glass at the higher temperature was typically 60-65% SiO_2, 30-35% Na_2CO_3, together with1-5% coloring material.

Producing colored glass and glazes was of particular interest. Colors of glass produced in this project, and the coloring material added, include the following. Blue glass resulted from adding $CoCO_3$, transparent amber from Fe_2O_3, and amethyst from MnO_2. Attempts to prepare red glass by adding Cu_2O resulted in teal colored glass, probably due to oxidation of copper(I) to copper(II).

The lovely blue color of cobalt blue glass is due to a relatively intense transition $t_2 \leftarrow e$ in the tetrahedral environment of $3d^7$ Co^{+2} ions in the silicate matrix, as interpreted in ligand field theory. In more detail, this transition is designated $^4T_1(P) \leftarrow {}^4A_2$ (Cotton, 1999; Hush, 1968).

CONCLUSION

In the present work, small samples of glass and glazes were produced by heating SiO_2 with selected oxides and carbonates in a high temperature furnace around 850∞C, with further work around 1350°C. Several types of colored glass were produced, including blue, amber, and amethyst. In cobalt blue glass, the color is due to a transition in the tetrahedral environment of $3d^7$ Co^{+2} ions in the silicate matrix. In ligand field theory, this transition is designated $^4T_1(P) \leftarrow {}^4A_2$ (Cotton, 1999; Hush, 1968).

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