Material Matters: Science Concepts
Docent Handout

Photochemistry of Silver Salts

To understand the fundamental chemistry of silver-based photography, we must look at the photochemistry of silver salts. A typical photographic film contains tiny crystals of very slightly soluble silver halide salts such as silver bromide (AgBr) commonly referred to as "grains." The grains are suspended in a gelatin matrix and the resulting gelatin dispersion, incorrectly (from a physical chemistry standpoint), but traditionally referred to as an "emulsion," is melted and applied as a thin coating on a polymer base or, as in older applications, on a glass plate.

Figure 1 shows a schematic representation of the silver halide process. When light or radiation of appropriate wavelength strikes one of the silver halide crystals, a series of reactions begins that produces a small amount of free silver in the grain. Initially, a free bromine atom is produced when the bromide ion absorbs the photon of light:

$Ag^{+}Br^{-}$ (crystal) + hv (radiation) --> Ag^{+} + Br + e^{-}

The silver ion can then combine with the electron to produce a silver atom.

$Ag^{+} + e^{-} \text{-->} Ag^{0}$

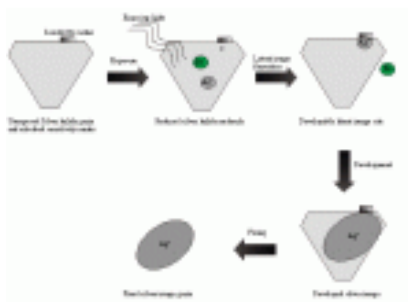

Figure 1: A Simplified Schematic Representation of the Silver Halide Process

Association within the grains produces species such as Ag_2^{+}, Ag_2^{0}, Ag_3^{+}, Ag_3^{0}, Ag_4^{+}, and Ag_4^{0}. The free silver produced in the exposed silver halide grains constitutes what is referred to as the "latent image," which is later amplified by the development process.

The grains containing the free silver in the form of Ag_4^{o} are readily reduced by chemicals referred to as "developers" forming relatively large amounts of free silver; that deposit of free silver produces a dark area in that section of the film. The developer under the same conditions does not significantly affect the unexposed grains.

The radiation or light sensitivity of a silver halide film (referred to in the trade as its "speed" and denoted on commercial film as its ASA in the United States or DIN in Europe) is related to the size of the grain and to the specific halide composition employed. In general, as the grain size in the emulsion increases, the effective light sensitivity of the film increases - up to a point. An optimum value of grain size for a given sensitivity is found to exist because the same number of silver atoms are needed to initiate reduction of the entire grain by the developer despite the grain size, so that producing larger grains reaches a point of diminishing returns and no further benefit is obtained.

All photographic emulsions contain crystals of varying sizes, but within a given emulsion the range is from less than 0.1 micron in slow emulsions (e.g., for paper prints) to a few microns in "fast" negative emulsions. From: http://www.cheresources.com/content/articles/other-topics/chemistry-of-photography

The Properties of Glass

Is glass liquid or solid?

There is no clear answer to the question "Is glass solid or liquid?". In terms of molecular dynamics and thermodynamics it is possible to justify various different views that it is a highly viscous liquid, an amorphous solid, or simply that glass is another state of matter that is neither liquid nor solid. The difference is semantic. In terms of its material properties we can do little better. There is no clear definition of the distinction between solids and highly viscous liquids. All such phases or states of matter are idealisations of real material properties. Nevertheless, from a more common sense point of view, glass should be considered a solid since it is rigid according to everyday experience. The use of the term "supercooled liquid" to describe glass still persists, but is considered by many to be an unfortunate misnomer that should be avoided. In any case, claims that glass panes in old windows have deformed due to glass flow have never been substantiated.
From: http://math.ucr.edu/home/baez/physics/General/Glass/glass.html

The Colored Glass Recipe:

The earliest people who worked with glass had no control over its color. Then, through accident and experimentation glass-makers learned that adding certain substances to the glass melt would produce spectacular colors in the finished product. Other substances were discovered that, when added to the melt, would remove color from the finished project.
In the eighth century, a Persian chemist, Abu Musa Jabir ibn Hayyan, often known simply as "Geber" recorded dozens of formulas for the production of glass in specific colors. Geber is often known as the "father of chemistry" and he realized that the oxides of metals were the key ingredients for coloring glass.

Colors of Duration: Many of the glass colors did not stand up to year-in, year-out exposure to the direct rays of the sun. The result was a stained glass scene of deteriorating beauty. Some colors darkened or changed over time, while others faded away.

Research and experimentation continued in an effort to meet the need for colors of duration. Eventually a full palette of fairly stable colors was achieved.

Metals Used to Color Glass:

The recipe for producing colored glass usually involves the addion of a metal to the glass. This is often accomplished by adding some powdererd oxide, sulfide or other compound of that metal to the glass while it is molten. The table below lists some of the coloring agents of glass and the colors that they produce. Manganese dioxide and sodium nitrate are also listed. They are decoloring agents - materials that neutralize the coloring impact of impurities in the glass.

Minerals: The Keys to Coloring Glass

The sources of the oxides, sulfides and other metals compounds used to color glass are minerals. The keys to beauty often come right from the Earth.

Metals Used to Impart Color to Glass	
Cadmium Sulfide	Yellow
Gold Chloride	Red
Cobalt Oxide	Blue-Violet
Manganese Dioxide	Purple
Nickel Oxide	Violet
Sulfur	Yellow-Amber
Chromic Oxide	Emerald Green
Uranium Oxide	Fluorescent Yellow, Green
Iron Oxide	Greens and Browns
Selenium Oxide	Reds
Carbon Oxides	Amber Brown
Antimony Oxides	White
Copper Compounds	Blue, Green, Red
Tin Compounds	White
Lead Compounds	Yellow
Manganese Dioxide	A "decoloring" agent
Sodium Nitrate	A "decoloring" agent

from: http://geology.com/articles/color-in-glass.shtml

Here is a site that is a fun introduction to coloring glass and modifying it in other ways.
http://chemistry.cmog.org/