

## **Ansel Atoms: The Chemistry of Photography**

From LCD screens to spaceships, chemistry has changed the world in ways that many people could not have imagined possible. With photography, however, it is a different case; during the mid-18<sup>th</sup> century, a man named La Roche wrote a fictional story about a canvas which was covered in a sticky substance. This canvas was able to capture images from the world around it, and once the sticky substance had become solid, the image would remain on the canvas permanently. Little did La Roche know that just a few centuries after his death the “magic canvas” would actually be created through chemical means (Leggat).

Few people recognize that chemistry plays a vital part in photography; without chemistry, the production and development of photographs would be impossible. From the first snap of a camera shutter to the development processes of film, photography is an art based solely on chemical reactions.

### **Chemicals and Supplies: Past to Present**

Since the development of photography first began, both its materials and practices have changed drastically. Originally, materials used for photography were difficult to handle, development could take up to eight hours and copies couldn't be made from one photograph.

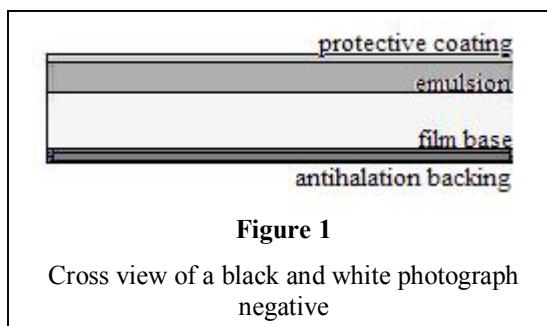
Instead, the only way to produce multiple copies of one photograph was to set up cameras right next to each other and take the picture at the same time using all of them.

Thankfully, since then, the technology used in photography has developed significantly. During the late

1800s, the metal sheets covered in asphalt, which were used as film, were replaced by a flexible film with silver halide salts dispersed through a gelatin material called emulsion (see Figure 1). This new film was made by American chemist Hannibal Goodwin and it is actually the basis of films made today. One thing that hasn't changed, however, is the process and the different lighting techniques used in photo developing. For instance, the Camera Obscura, also known as the dark room, has existed for over four hundred years (Leggat). The contents of the dark room, such as stop baths, fixers, and final washes, have also remained the same as they were when photography first began, although they are not necessarily made from the same chemicals.

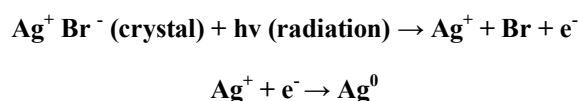
### **Taking a Picture**

It is a common misconception that the chemistry of photography only begins to take place during the

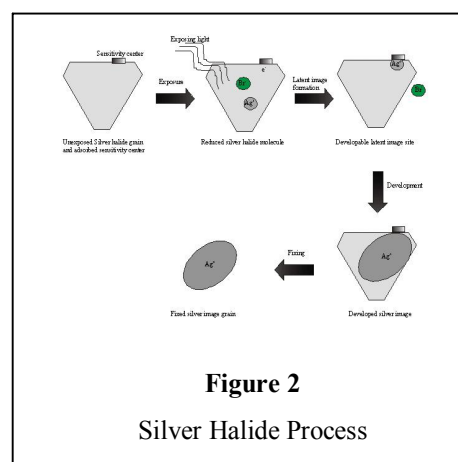


processes of development. In truth, chemistry in photography not only occurs during development, but during the actual procedure of taking a picture. This is due to the photochemistry of the silver halide salts in emulsion.

When a camera shutter opens to take a picture, the film is exposed to light particles. The photons either combine with a silver halide salt and form a reaction, or pass through the emulsion until they reach an anti-halation layer, which can be found in front of, or behind, the film base (Naugler). The anti-halation backing absorbs the light which did not create a silver halide reaction and keeps this light from reflecting into the emulsion again, preventing excess reactions and contrast. The light photons which do create a reaction, however, play a central part in the conversion of silver ions to silver atoms as seen in the equation below (Myers).



In this process (see Figure 2) the silver halide particles (silver and bromine ions) combine with radiation to form a free bromine atom, as well as a free silver ion and an electron, which is made from the light photon releasing an electron from the silver halide molecule. The free silver ion then combines with the electron to produce a silver atom. The silver that is produced in the grains of silver halide is then turned into the “latent image formation.” The “latent image formation” is a configuration of clustered silver atoms which are grouped on the silver halide particles after the silver atoms have been reduced due to the light and silver ion reactions. This

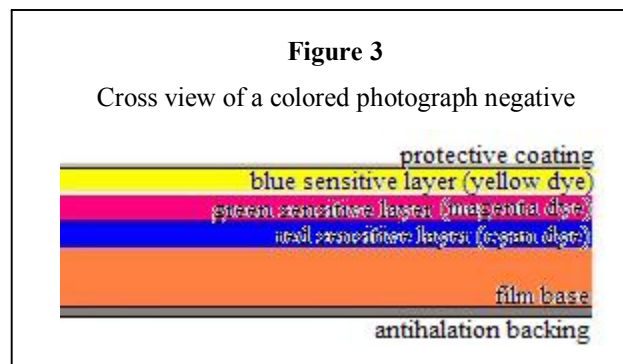


**Figure 2**  
Silver Halide Process

formation is what, during the photographic development stage, will become the actual image of the photograph that had been taken. This method, however, only pertains to black and white photographs.

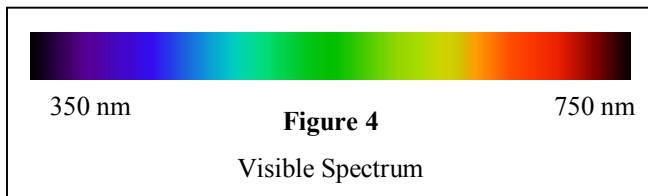
**Taking a Picture with Colored Negatives**

Photographs taken with colored negatives go through a reaction almost identical to that of a photograph with black and white negatives; the only difference is that the composition of a colored photo negative is unlike that of a black and white photo negative. The emulsion in a colored negative is made



**Figure 3**  
Cross view of a colored photograph negative

of three different layers. These emulsion layers still contain the silver halide particles that the black and white photograph negatives include, but the silver halide particles are coupled with unique dyes, and each layer has sensitivities to different wavelengths of light, as seen in Figure 3. The dye colors compliment the color sensitivities of each layer. For instance, the first layer of the colored negative has a yellow dye because of its sensitivity to blue wavelengths, the second layer of the colored negative has a magenta dye because it is sensitive to green and the third layer has a blue dye because of its sensitivity to red wavelengths. However, because all of the layers are sensitive to blue wavelengths, there is a filter between the second and the third layer. This filter is called the colloidal filter, and it is removed during the development process. The orange film, at the bottom, is used to reduce contrast and make up for mistakes in the green and red sensitive layer.



The human eye can only respond to wavelengths between 350 -750 nm (see Figure 4), which means that the silver halide's sensitivity, which is sensitive to radiation only up to 525 nm, has

to be widened using "color sensitizers" or dyes. The dye helps to absorb wavelength energies that the silver halide couldn't and then reassigns the energies to silver halide particles to form the latent image for the colored negative.

### **Development**

During development, the chemical change which produced the latent image formation is magnified so that it is visible to the naked eye. In order to do this, the silver halides that have had photon reactions are reduced to metallic silver in the emulsion. Generally, the darkness of an image is decided during this process, because the longer the developer (usually a developer such as hydroquinone, metol, or phenidone) works, the more silver is produced from the silver halide salt reduction. According to Dr. Drew Myers, the speed at which development takes place can rely on many different variables, such as "the rate of diffusion of the solution through the gelatin matrix, the absorption of the developing agent, the solution of the silver halide, oxidation products of the developing agent and the accumulation of restraining by-products." The rate of development occurs differently with certain emulsions and developing agents. One way that the rate of development can be discovered is through the change in density from the silver halide salts to the metallic silver particles. However, finding the rate of development through this process is made difficult through the increase of both silver and/or number of particles in the development procedure. The density increases quickly until its rate of growth begins to plateau, which signifies that the

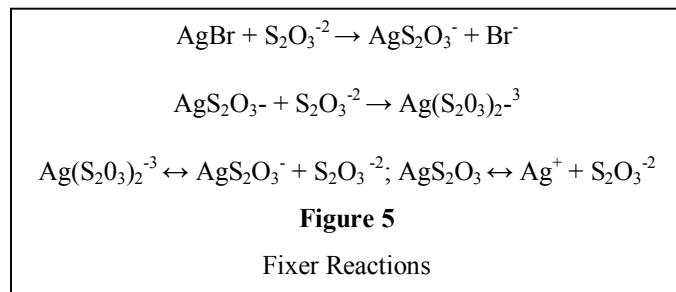
development is complete. Extended contact of the film with a developer can cause the development of grains that had not been exposed to photons, leading to an increase in the density and what is commonly referred to as “fog.” Fog can be reduced using a restrainer, such as potassium bromide, which helps to slow down the development of silver particles that have not been exposed to photons of light. The development of colored film produces not only a color image, but also a black image. As the developer reduces the silver halide particles, it actually oxidizes. The oxidized developer can then react with the color dye couplers in the emulsion and create a colored dye.

### **Stop Baths**

Once the development on the image has been completed, the process must be stopped by chemical means to prevent overdevelopment. This is when a stop bath is used. Developer liquids generally consist of a liquid with a relatively high PH level, so weak acids or base liquids are used to stop the development process. Usually the acid works so quickly that the image only needs to go through the stop bath for a few seconds.

### **Fixing and Hardening the Image**

The fixing process is performed with the purpose of removing the residue of unexposed and undeveloped silver halide from the emulsion layer. If the remaining silver halide particles are not taken out of the emulsion layers, the image will continue to darken and eventually fog over time. Because of the fact that silver halides are practically



insoluble in water, chemical processes are needed to convert the silver halides into soluble particles. “Hypo,” also known as sodium thiosulfate has been used to convert these remaining silver halide particles to soluble complexes since the 1800’s. A

fixer may also contain stop bath and a hardener to prevent swelling in the gelatin during the last step, washing. In order to solubilize the silver halide, the thiosulfate ion reacts with it to create silver thiosulfate, which removes the silver from the crystals and therefore more easily removed from the film. However, the more the fixer solution is used, the more slowly the fixer solution will be able to remove the residue of the silver halide salts, and if the solution is used too much it won’t be able to eliminate the silver halide salts. Once the film has been developed and fixed, the last thing to do is rinse it off with plenty of water and hang it up to dry.

## **Conclusion**

La Roche's prediction in the 1700's paved the way for brilliant discoveries in centuries after his death. However, were it not for chemistry, La Roche's "magic canvas" would never have been invented. When most people think of photography, the idea of an art combined with science is rarely what first comes to mind. But the relationship formed between chemistry and art through photography is just one example of the ability of modern technology to bridge the gap between two seemingly diverse branches of learning. Similar to the coupled dyes in color photography, photography helps to unite two distinct fields of study in a way that compliments them, which has not only resulted in scientific advancements, but also in a more artistic society and evolved culture.

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