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Art and Chemistry - a Source of Mutual Inspiration and Symbiosis
Inquiry-based learning as deeper understanding of curriculum in chemistry science through arts

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Abstract

Chemistry students are sometimes bored or turned off by a traditional approach to chemistry. Integrate chemistry and art with hands-on activities and fascinating demonstrations that enable students to see and understand how the science of chemistry is involved in the creation of art. Most importantly, the chemistry is taught with relevance to art topics. Art and chemistry are truly integrated into one subject [2].

In ancient times, chemical science has served art - it has studied the composition of colors. “We employed in our researches ultramarine of various qualities; but that used in the experiments from which we have deduced the approximate proportions of its constituent principles was of the greatest beauty”, wrote Desorves and Clement in 1806 in A Journal of Natural Philosophy, Chemistry and the Arts [4].

In turn, artists are inspired by chemical reactions, structures, crystals, diffusion and other visualizations. However, although we are capable of creating art at a young age, for many of us this inspirational, artistic and creative chapter of our lives ends as we move onto more “mature” endeavors.

How to keep inspiration for artistic creativity in the long run? The author shares the experience of getting inspiration from the results of chemistry experiments. As argues Prof. Omar Yaghi**: “**Metal–organic frameworks are some of the most beautiful compounds ever made**.** Their structures are intricate and the diversity of structural patterns and connectivity, to me, they are fascinating. I love looking at molecular structures and the periodic table, and how that translates into compounds, reactions, materials, and new chemistry.” [6].

Keywords

Art, Chemistry, Creativity, Symbiosis

1. Introduction

Art is a made of expression and craftsmanship. Science is the practice of making observations about physical properties of the world. The two disciplines are arguably distinct opposites from one another. The course combines theoretical science concepts with current art practices to provide a greater understanding of chemistry's role in art and show how the nature of color relies on chemical processes.

"The students actually do labs which are effectively art studio practices and then we talk about the science of the labs themselves," Coppage [1] said. "I bring in art conservationists, I've brought in a restorationist that has worked on $50 million paintings, anything that I can possibly get my hands on that talks about the intersection between science and art."

Coppage structures his class by giving a lecture on a type of art, its history and its uses in modern times. He then talks about the science of how the methods works, such as the elements of composition, recipes and different pigment compositions.

"For example, we did a ceramics lab in which we used a 5,000-year-old Egyptian faience recipe where they would make the little turquoise statues of the Egyptian gods," said Coppage. "I provided an adapted recipe for them, they molded their own statues. The students had to write up a lab report about the actual science of the material, what caused the color, how it was fired, why it was the color it was, how it was hard or petrified."

"For me, it's about education," he said. "If someone is interested in art I think that if they understand what they're doing a little bit more, it widens their perspective. All of a sudden, they're not confined to the small amount of rules they have set in front of them. They can go in any direction they want if they understand the parameters they have."

Through finding a medium between two fields of study that seem drastically different from one another, Coppage's students are encouraged to look for further correlation among their academic endeavors.

2. Historical view to symbiosis of Art and Chemistry

The history of chemistry began more than 4,000 years ago with the Egyptians who pioneered the art of synthetic "wet" chemistry. By 1000 BC, the ancient civilizations were using technologies that would form the basis of the various branches of chemistry. Extracting metal from their ores, making pottery and glazes, fermenting beer and wine, making pigments for cosmetics and painting, extracting chemicals from plants for medicine and perfume, making cheese, dying cloth, tanning leather, rendering fat into soap, making glass, and making alloys like bronze. In the Middle Ages that began around 500 AD and lasted until 1400 AD there was a “science” called alchemy - the forerunner of modern chemistry. The main objectives of alchemy were to find the appropriate combination of ingredients that would cure all illness and diseases, to find the chemical that would prolong life, and to convert lead into gold. Nowadays the above goals have not been neglected – possibly just realistically modified.

During the Renaissance, artists were chemists and chemists were artists. The close relationship between art and chemistry is still obvious to the artist and to the chemist, but todav there is little need for the artist to prepare his or her own materials. On the other hand, this relationship provides a viahle curriculum for an interdisciplinary approach to the teaching of chemistry.

In 1984 a one-year high school course “Art in Chemistry” was developed by Barbara Greenberg who was a teacher in the faculty of Willow Brook High School, Villa Park. The chemistry courses in the curriculum are approached through art topics: Color, Painting Surfaces, Clays and Glazes, Jewelry Making, Photography, Art History, and Chemical Hazards in Art. In each of these seven units, the students completed projects in the art class and carry out experiments in the chemistry class. There were a total of 20 chemistry experiments and two chemistry demonstrations. There were 11 art lessons, some including projects and questions. The art proiects employed the materials prepared in the chemistry experiments. Each of these units was original and could be supplemented with any general chemistry and introductory art textbook. A brief overview of each of these units is described in this paper.

The art teacher presents lectures on the historv -. of painting materials and art forgeries. Two chemistry experiments are done on this topic: “Art Forgeries-Radioactive Dating” and “Art Forgeries sectroscopy and Qualitative Analysis for Ions”. The first provides a basis for a discussion of halflife in radioactive substances and its use in radioactive dating. In the second lab, the student works with an “original” painting and an art “forgery”. The idea behind the experiment is to show a general technique for detecting art forgeries and to teach qualitative analysis. A paint chip is taken from each painting and put through flame tests. Next a chip is analyzed for lead (II), silver, and mercury (I) cations (V). The presence of lead ions can identify an “old painting since it is assumed that most artists no longer use lead-based paints. The final lesson in this unit is in art class dealing with the preservation and restoration of works of art. Much of the teaching is done through movies: “Art of the Conservator I and II”, “Once Upon A Wall”, “The Great Age Of Fresco”, and “Treasures of Florence”. A trip is scheduled to the Department of Conservation at the Art Institute of Chicago.

3. Color

The first unit is on Color. It includes art lessons on the nature and meaning of color and color relativity. The students prepare a color wheel with 12 hues, make a chart using light and dark values (degrees) of one hue, and learn about the nature, source, and traditional significance of each hue. To study color relativity, the students place colored squares on various backgrounds and note the effect of the comhination on the value of the square. This exercise leads into the first chemistry experiment entitled: “Why We See Color When Certain Atoms Are Excited”. The spectroscope is used to see spectral lines from excited atoms in the gaseous phase. The spectral lines are explained in a qualitative way. Atoms, neutrons, and electrons are discussed. Several paint-making experiments are then conducted. Pigments are prepared by precipitating aqueous ions, as a combustion prduct, from a mineral source and from reactions with organic and inorganic substances. This chemistry experiment teaches the students about chemical change, how atoms combine to make molecules, and about chemical formulas and equations. The students also learn how to filter and decant, how to use a Bunsen burner, and how to work safely in the lab. In the next experiment, the students compare the solubility of each prepared pigment in H_2O, oil, egg yolk, 6 M NaOH, and 6 M HCl. The third chemistrv lab involves the preparation of binders for oil paints, water paints, and egg tempera. The final exneriment in this color unit focuses on the preparation of by combining homemade replicas of commercial binders with the previously prepared pigments. Binders iuclude oil; a water, wax, and ($NaHCO_3$) combination; egg yolk; and a starch and cold water mixture. Some combinations form suspensions while others form solutions. This experiment is used to teach solutions, suspensions, colloids, and physical change. Since the Color Unit experiments include all classes of matter, it is appropriate to introduce classification of matter into heterogeneous mixtures, - homogeneous mixtures, elements, and compounds.

4. Painting Surfaces

The art lesson for the Painting Surfaces unit, includes forms of paints and the ways paints are applied to surfaces. Students compare the composition of watercolor, acrvlic, and tempera paints. They learn the procedure of stretching and preparing canvases and watercolor paper and discuss the properties of a gesso painting surface. In the chemistry section of the unit, student experiments include: preparation of grounds using whitening compounds to make gesso suspensions and the making of paper. A whitening compound, $CaCO_3$, is made by precipitation from 0.2 M Na_2CO_3 and 0.2 M $CaCl_2$. Slaked lime, $Ca(OH)_2$, is prepared from solid CaO and H_2O. These combinations illustrate double replacement and composition reactions. In the gesso preparation, $CaSO_4$. H_2O is used. These experiments afford a good opportunity to renew equation writing and classification of chemical reactions, and to define terms such as hygroscopic, efflorescence, deliquescence, hydrate, and anhydrous. Two methods of paper making are presented: making paper from lint and making paper from sawdust. The use of sodium hydroxide to digest the wood fibers provides the impetus for the discussion of acids and bases. After the paper is made, it is used in an art lesson to make a picture with the paints prepared in Unit 1.

5. Clays and Glazes

To learn about clays and glazes in art, the students study the nature of clay and ceramic techniques. They discuss clay as a natural polymer while preparing clay slabs and clay objects. In chemistry, the students study relative weights of dements, learn about the mole concept, and make simple conversions in preparation for the next experiment where they make glazes. These glazes are applied to the surface of the clay slabs, fired in the kiln and observed for color, shininess, and texture.

6. Texture and Line

In an art lesson on texture as an element of design, a plaster of Paris mold is poured, hardened, and a design is scraped into the surface. This mold is used in the next chemistry experiment: “Preparation of Polymers”. The students prepare Lucite, a glyptal resin, and nylon. The Lucite is poured into the mold and set. The nylon is used in their next art lesson: “Line as an Element of Design”. Here the students make a three-dimensional toothpick sculpture and incorporate the nylon filament into the sculpture. The final chemistry lesson of this unit on polymers is used as an introduction to organic chemistry.

7. Jewelry Making

In the Jewelry Making Unit, the first art lesson focuses on basic metal-working techniques. The students learn to solder, saw, file, and polish metal and to use tools properlv to prepare an original piece of jewelry. In chemistry, they examine the physical and chemical properties of metals including density, approximate melting point, metals, reactivity oxygen, HCI, H_2SO_4, and HNO_3. The chemistry discussion includes an inveitigation of the periodic table and the trends associated with the physical properties within the group,. An activitv series for the metals is developed from the observations of reactivity to acids. The next chemistry experiment is that of preparing alloys of metals and observing their properties. Jewelry is made through an electroplating experiment that introduces the students to electrochemistry. The parts of an electrolytic cell are presented, and red-ox reactions are introduced. In this activity the students use copperplate metal ohjects they have made in art class. For the last metal experiment, the students prepare four solutions that react with copper strips and change the color of the surface. Thev write equations to find the products that were responsible for the change in colors. Since jewelry is usuallv three dimensional. there are two chemistrv experiments chat relate to three-dimensional objects: “Making Molecular Models” and “Ion or Atom Arrangements of Crystals”. These introduce the topics of intramolecular bonding in molecuies and intermolecular and ionic honding in solid structures with the building of molecules and crystalline solids. The last art lesson for this unit on Jewelry Making is related to the principles of organization in two and three-dimensional works. Sculptures are studied for good composition stressine a successful arraneement of line. color, shape, contrast of light and dark area and texture: The molecule and crvstalline structures studied in the chemistry class are used as design motifs for sculpture construction.

8. Photography

Photography starts with two chemistry experiments. "Developing Film and Printing the Negative or Photogram". The students prepare each solution necessary to develop film and to make prints. They learn the chemical principle behind each step in the print-making process. Students prepare photograms in the second chemistry experiment and use them for the art lesson, "Negative and Positive Space Organization". A photogram is a photo made in the darkroom through direct exposure of objects on light-sensitive paper. A camera is not needed for this picture. A sulfide sepia toner and a brown toner are combined and applied to the photograms in the final chemistry experiment in this unit which is "Photography-Toning Prints".

9. Chemical Hazards in Art

A combined chemistry and art presentation on chemicals used in art includes topics of toxicity and proper use of materials. Examples are given, i.e., metal working can produce toxic heavy metal fumes and acids used to etch metal surfaces are corrosive to eyes and skin. Solutions used in photography are extremely toxic if ingested and can irritate the skin upon contact. The students are told that chemicals can affect them by being inhaled or ingested or by being absorbed through the skin. Toxicity, however, does depend on the degree of exposure. There is a discussion on the ways to reduce-chemicai hazards. A presentation follows on ceramic materials and how the obiect should he handled during firing.

The course covers most of the topics taught in introductory art and the qualitative aspects of a beginning chemistry course. Accordingly, it does not deal with gas laws. percent composition of compounds, empirical and molecular fomulas, calculations, and other quantitative aspects of beginning chemistry. Materials described for each unit are dispensed as needed. The success of the course has resulted from the joint planning and interaction between the art and chemistry teachers who team teach the course.

10. Chemistry as source of mutual inspiration

Chemistry is the science concerned with the composition, structure, and properties of matter, as well as the changes it undergoes during chemical reactions. The latter is defined as "a process in which one or more substances are changed into others."

Chemistry is generally divided into inorganic chemistry and organic chemistry where another division is physical chemistry and analytical chemistry. Chemical reactions are processes by which the original substances are changed into new ones by making or breaking of chemical bonds. Interesting reactions, not yet well understood, are those taking place in our brain. When we think a thought or feel a sensation from the outside world, it is the result of chemical reactions in our brain; drugs and food can have a significant effect upon our brain chemistry. Each chemical is characterised by a symbol or a formula derived from the scientific name of the element where a specific reaction is described as combination of the formula of the reactants and products, for example A B. It is interesting to note that also in the brain there are reactions caused by the brain cells, when for example we see something attractive. And finally, two additional basic definitions. Chemistry laboratory is defined as “a laboratory for research in chemistry” or “a workplace for the conduct of scientific research” where the chemist is “a scientist who specialises in chemistry”. The original physical chemistry laboratory was built in Oxford University in England [3]. In the following different aspects of chemistry are demonstrated by artworks.

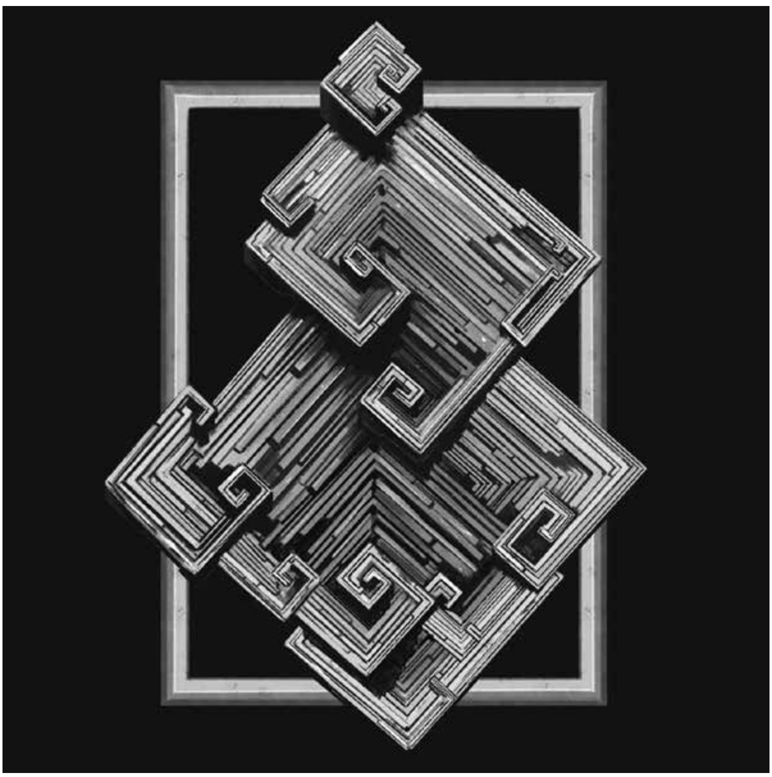

Figure 1

Figure (1) Bismuth is a heavy, brittle silver-white crystalline that transforms with tinges of pink to red. It naturally occurs with an iridescent oxide tarnish that reflects a full spectrum of colors including blue, yellow and green, as well. Bismuth crystals are typically laboratory grown where Bismuth is melted and a rod is placed in the molten metal and pulled up slowly, which allows crystals to form as it cools. [7]

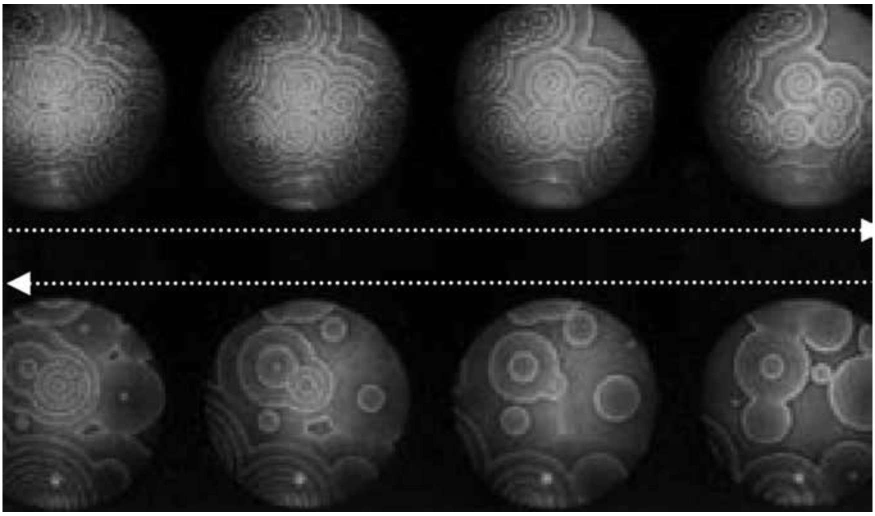

Figure 2

A cyclic process is demonstrated in Fig. (2). It is the Belousov - Zhabotinski "chemical cyclic reaction" [3] named after two Russian scientists where Belousov discovered the reaction in 1951. This chemical reaction occurs by mixing four compounds, which then create beautiful rings, which spread across the plate. The reaction oscillates back and forth between different colored states in rings, which move in rhythmic wave patterns. In the reaction ferroin continuously shifts and forms its oxidized form ferriin through different intermediate species. In the picture we see top views, at different times, of the surface of the apparatus in which the oscillatory chemical reaction takes place.

Figure 3

Another kind of chemical reaction, "The Firework", which combines art and science, is demonstrated in Fig. (3). Fireworks are usually made out of the following mixture: an oxidizing agent, a reducing agent, coloring agent, binders and regulators. When these are mixed together and burned, they produce the spectacular effects.

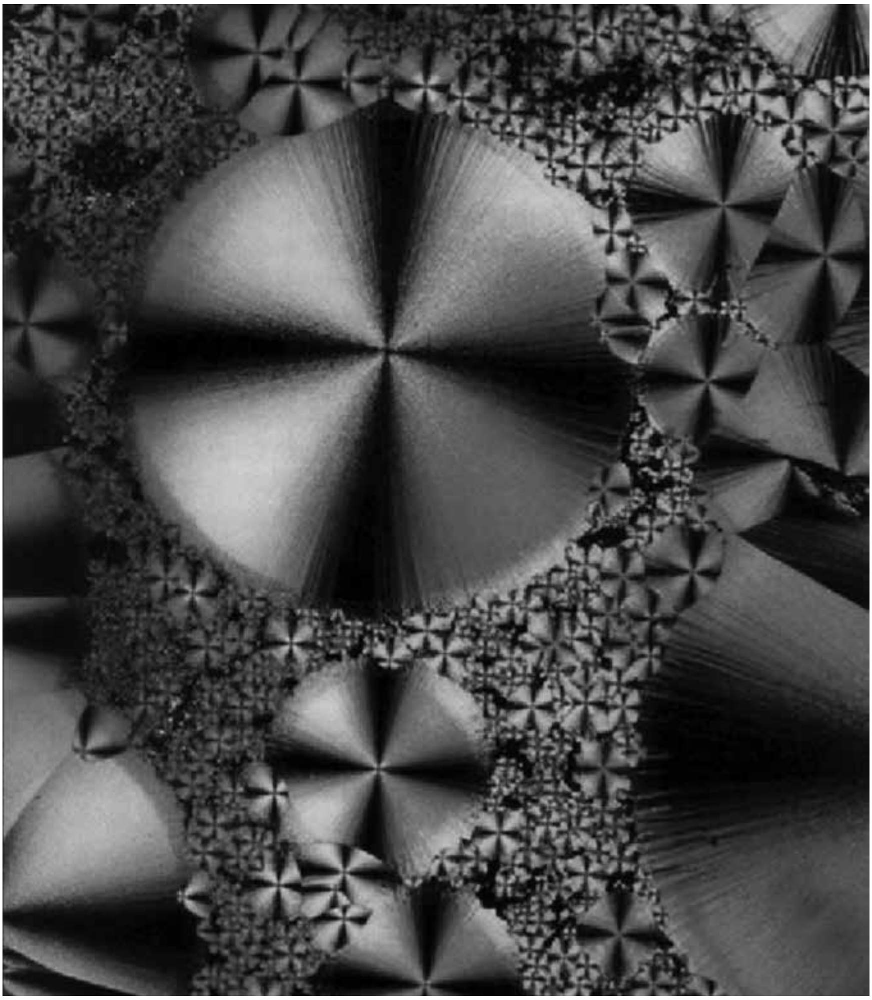

Figure 4

Fig. (4) demonstrate science creating art in images of different chemicals photographed by the research scientist Michael W. Davison through a microscope, or more commonly by photomicrography. This is a photograph of vitamin B1. [8]

11. My personal experience in Art and Chemistry

Personally I have grown bismuth crystals, made chemical gardens out of water glass and different kinds of salts, grown metal salt crystals and made crystal tree sculptures, used chemical reactions and diffusions for my artworks.

Growing bismuth crystals at home is far too dangerous because it requires to deal with molten metal. In the laboratory I took around 500g of bismuth and melted it in a porcelin bowl on a heating mantle to ensure even heat and covered in aluminium foil. It is then cooled slowly and evenly which is vital for creating crystals. After a solid crust of bismuth forms on top of the bowl it is then broken or punktured and the molten bismuth is poured out of the bowl in to a different container and you are left with some beautiful bismuth crystals. This experiment taught me that metals have crystal forms and that their crystal structure depends on the unitcell properties. This can also teach one of the most widely used purification methods of crystaline substances and it's recrystalisation.

Chemical garden is made out of the solution of sodium or potassium silicate (water glass) and different kinds of inorganic salts. When a metal salt, such as cobalt chloride, is added to a sodium silicate solution, it will start to dissolve. It will then form insoluble cobalt silicate by a double displacement reaction (anion metathesis). This cobalt silicate is a semipermeable membrane. Because the ionic strength of the cobalt solution inside the membrane is higher than the sodium silicate solution›s, which forms the bulk of the tank contents, osmotic effects will increase the pressure within the membrane. This will cause the membrane to tear, forming a hole. The cobalt cations will react with the silicate anions at this tear to form a new solid. In this way, growths will form in the tanks; they will be colored (according to the metal anion) and may look like plant-like structures. The crystals formed from this experiment will grow upwards, since the pressure at the bottom of the tank is higher than the pressure closer to the top of the tank, therefore forcing the crystals to grow upwards.

After the growth has ceased, the sodium silicate solution can be removed by a continuous addition of water at a very slow rate. This prolongs the life of the garden.[9]

I made this experiment in some little jars using copper(II) sulphate, iron(II) sulphate, cobalt(II) chloride and chromium(III) chloride. After the 5 years of being made it hasn't changed it's state. This experiment taught me of the double replacement reactions and on how it forms insoluble salts. The crystal growth upwards showed me the osmotic process and how pressure and density effects the growth rate. As shown in figure (5) but that is not a picture of my chemical garden, it is of Neda Glisovic.

Figure 5

To grow metal salt crystals in water you have to go through a similar path as with the previous two crystal growng methods mentioned in this topic. At first I chose a metal salt with a steady growth in solubility increasing the temperature. This ensures that whilst cooling the solution the crystals will have time to grow graduately so the biggest monocrystals form. At first I created a saturated solution at about the temperature of 80oC. In this beaker was then added one monocrystal of the same salt the solution was then cooled to room temperature and left for a couple of weeks. The monocrystal should then be at the bottom of the beaker. The crystal tree sculpture is made in the same way only in the hot solution instead of the monocrystal there is a tree shape structure submerged in the solution. The tree shaped structure is made out of wire which branches are wrapped with twine cowered with a bit of small salt crystals. The crystals ensure crystalisation centers. The monocrystals on copper(II) sulphate are shown in figure (6)[10] and figure(7) shows my crystal tree.

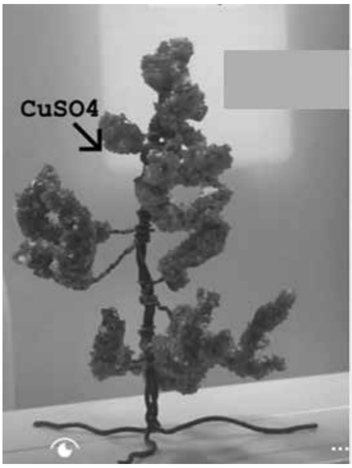

Figure 6

Figure 7

I have also used some chemical reactions or properties on paper to create art pieces. This would envolve using salt on a pool of watercolor, mixing paints of nonpolar and polar bases, combinging acids with carbonate salts and pigments on top of a piece of paper to form interesting patterns, textures and effects. These kinds of experiments taught me diffusion, acid reactions with carbonates, nonpolar and polar liquid properties etc. As shown in figures 8 watercolor with salt by Joe Millet and figure 9 acryllic paint pour with polar and nonpolar bases[11].

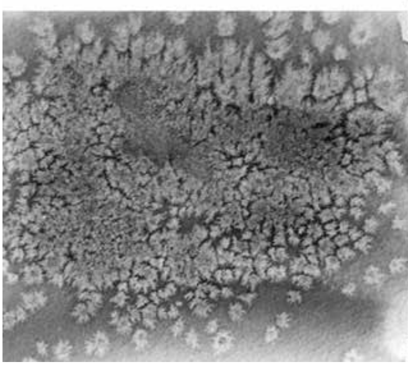

Figure 8

Figure 9

12. Conclusions

To conclude the observation, the author is fully agreed with Abraham Tamir that the presentation by artworks of the different areas in Chemical Engineering makes this profession clearer, more understandable, easy to percept as well as to remember, especially for students -beginners. One of the most impressive influence between chemistry and art is personnal experiance by working with materials and inspiration of chemical eksperiments – the aesthetic and artistic images of crystal lattices have inspired the creation of new works of art.

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