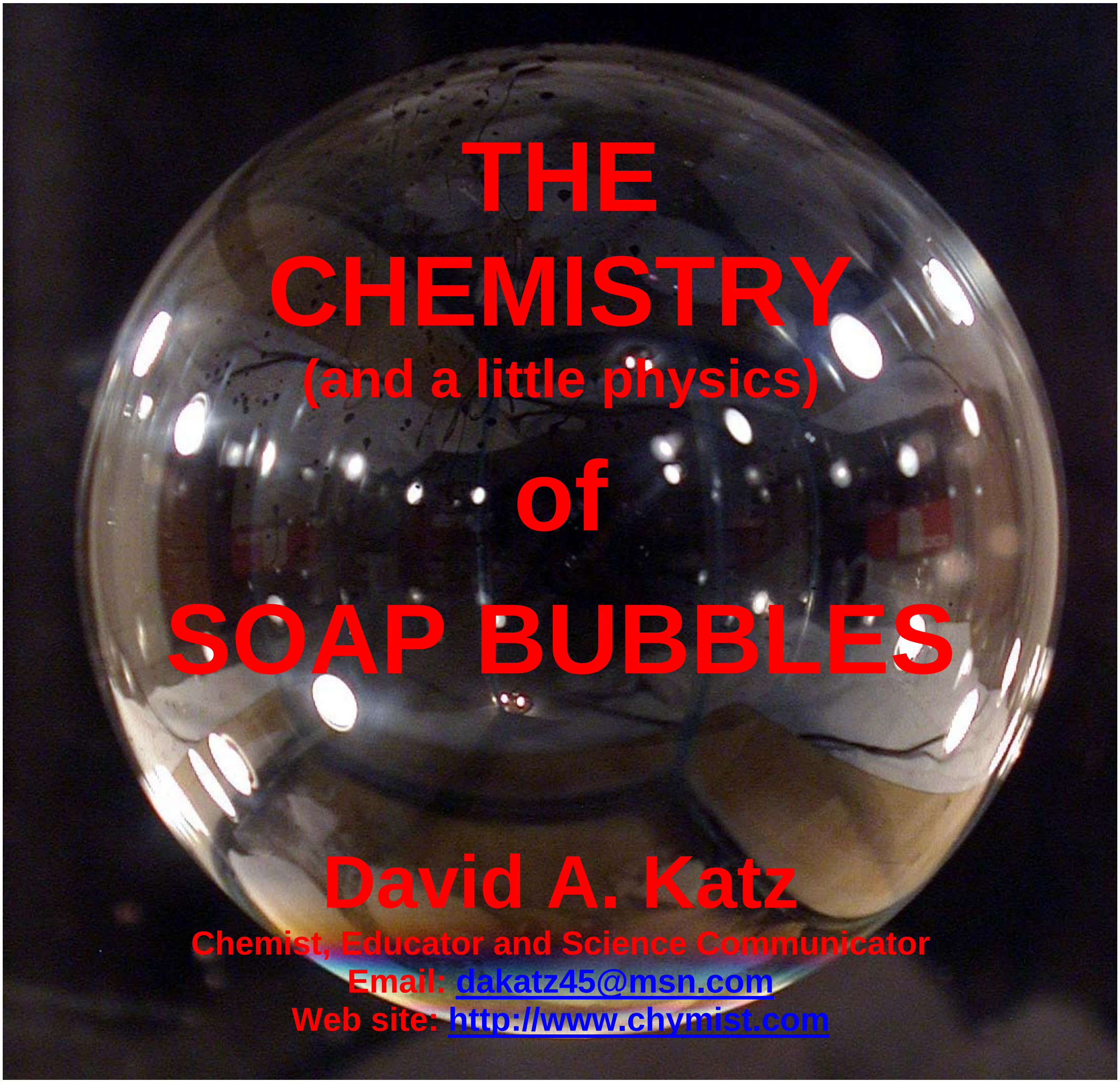

THE CHEMISTRY

(and a little physics)

of

SOAP BUBBLES

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Long Lasting Bubbles

There are two types of long lasting bubbles that the author has experimented with, sodium 9,10-dibromostearate (also known as Kuehner's formula. See Appendix.) and polyvinyl alcohol bubbles (also known as Grosse's formula)

Sodium 9,10-dibromostearate

Using Kuehner's formula, the author prepared sodium 9,10-dibromostearate solution and successfully used it to blow bubbles, in a glass jar, that lasted for over a month. (See Experiment 18) The author did not, however, try to maintain the bubbles for longer time periods. A modified procedure for preparing sodium 9,10- dibromostearate is given in the appendix.

Sodium stearate, the soap upon which this procedure is based, makes a good bubble solution. (The structure of sodium stearate is given in Figure 6. A space-filling molecular structure of the stearate ion is shown in Figure 19.) Adding bromine atoms to the sodium stearate molecule places large atoms in the middle of the carbon chain that makes it difficult for the tangled soap molecules to become untangled. Thus, the soap film is less likely to break. (See Figure 20)

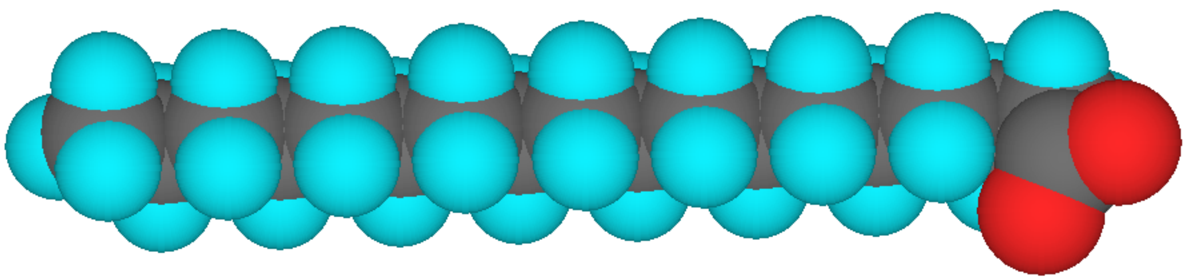

Figure 19. A space-filling model of the stearate ion

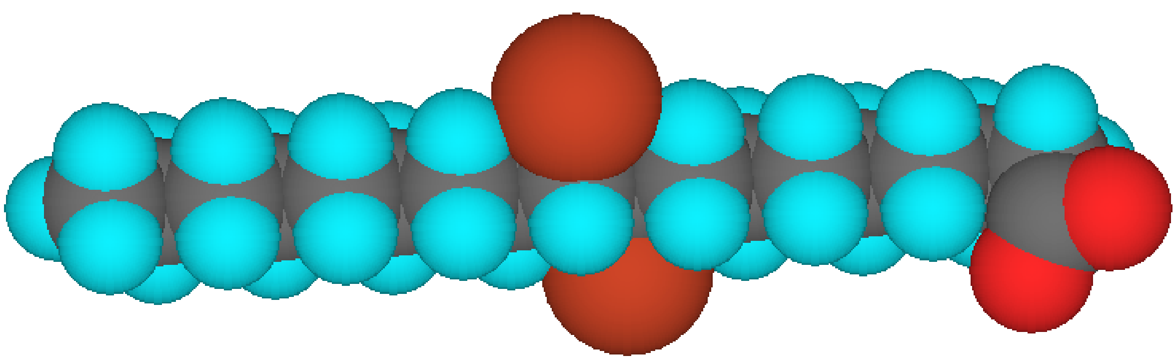

Figure 20. A space filling model of the 9,10-dibromostearate ion

Experiment 18. Producing long lasting soap bubbles

Materials Needed

Large wide-mouth glass jars with lids, quart size or larger (Jars should be clean and dust free. For best results, wash the jars and lids in a dishwasher, but do not use a rinse aid.)
Watch glasses or petri dishes to fit inside jars (A watch glass is preferred. Watch glasses and glass petri dishes are best cleaned in a dishwasher with out any rinse aid being used.)
Soda straws
Soap bubble solution (Note: the sodium 9,10-dibromostearate solution is preferred for this activity, but any soap bubble solutions may be used.)
Water

Procedure

Place a small amount of water in the bottom of the jar. There should be just enough water to make a thin layer on the bottom edges of the jar but not to cover the raised center of the jar bottom. The water is used to maintain a constant humidity in the jar.

Place a clean watch glass or petri dish in the jar.

Using a soda straw, place some soap solution in the watch glass or petri dish.

Blow a bubble in the watch glass. It should not be large enough to reach the edges of the watch glass.

Close the jar with the lid. Place the jar with the bubble in a cool, vibration-free area away from direct sunlight. How long does the bubble last? (Note: The first bubble may break after a short while. If that happens, use a clean soda straw, dipped in soap solution, to blow another bubble. Do not add additional soap solution to the jar.)

Polyvinyl alcohol bubbles

Dr. Aristid V. Grosse reported long-lasting bubbles made with a polyvinyl alcohol solution. Although these bubbles are described in several publications, the exact formula for the bubbles was not reported.

To make polyvinyl alcohol bubbles, a 4% solution, by weight, of polyvinyl alcohol was prepared (See Appendix). Solutions were then made using Ultra Joy dishwashing detergent at concentrations of 2%, 4%, 6% and 8% by volume. Bubbles were blown onto a ceramic tile surface using a soda straw.

The longest lasting bubbles were produced by the 2% detergent solution. These bubbles did not break, but eventually deflated onto the tile surface. When blown from a straw and suspended in air, the bubble formed a plastic skin as the water evaporated and finally deflated to a smaller size.

Bubbles produced with a 4% solution of detergent in polyvinyl alcohol were not as long-lived as those made with a 2% detergent solution. Their behavior was similar to that of the 2% solution.

Bubbles made with the 6% and 8% detergent solutions did not last as long and either deflated or burst toward the end of their life spans.

Solutions containing 6% and 8% polyvinyl alcohol, by weight, were prepared and mixed with 2% Ultra Joy, by volume.

Cleaning Up and Storage

Soap solution can be reused if it is not dirty or contaminated with any metal ions, particularly iron (or rust). It gets better with age. Save the soap solution in an air tight plastic bottle or container. The 2-Liter bottles from soft drinks work well, so do 2 ½ gallon plastic gasoline containers. (5 gallon containers get too heavy) Remember to remove any labels from the containers and put a new label on the container that says "Soap Solution". You may also want to put the formula used to make the soap solution on the label along with the date it was made. Store the soap solution in an area where it will not freeze if the winter temperature gets too cold.

Remove excess bubble solution from the surface by using a squeegee to scrape it into a bucket or tray. (A squeegee works best, but paper towels will also work.) Do not add water. Then sprinkle a small amount of vinegar on the area to cut any remaining soap film. Wipe the surface dry with paper towels. If the surface is still soapy, repeat the procedure.

Bubbles Bibliography

Books

Barber, Jacqueline, **Bubble-ology**, Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley, 1986.

A teacher's guide of activities with bubbles for grades 6-9. Devise bubble blowing devices, test to see which soap makes the best bubbles, and make long lasting bubbles. Each activity lists all materials needed, skills developed, themes, and complete directions from preparation to clean-up.

Boys, C. V., **Soap Bubbles**, Dover, 1959.

A reprint of the 1911 edition. Everything you wanted to know about soap bubbles and surface tension. Many simple experiments and demonstrations are explained along with excellent engravings.

Cassidy, John, with Stein, David, **The Unbelievable Bubble Book**, Klutz Press, 1987.

This book accompanies David Stein's *Bubble Thing*. Includes recipes for bubbles, methods for making large bubbles, troubleshooting, homemade bubble machines, and additional bubble lore. Also included are articles on Bubble People.

Faverty, Richard, with Javna, John, **Professor Bubbles' Official Bubble Handbook**, Greenleaf Publishers, 1987.

Information about bubbles, bubble wands, and other bubble toys. Includes recipes for bubble solutions and instructions for all kinds of bubble tricks.

Isenberg, Cyril, **The Science of Soap Films and Soap Bubbles**, Dover, 1992.

Good discussions of the molecular basis for soap bubbles. A more mathematical treatment of soap bubbles and films than Boys' book with some excellent color plates.

Noddy, Tom, **Tom Noddy's Bubble Magic**, Running Press, 1988.

Using commercial "bubble juice", Tom Noddy explains how to do many bubble tricks such as caterpillar bubbles, a bubble carousel, and more. Brief explanations of what bubbles are and why they behave as they do.

Rämme, Göram, **Soap Bubbles in Art and Education**, Science Culture Technology Publishing, Singapore, 1998.

A well illustrated book, with many excellent photographs, which is a collection of papers published by the author. Covers topics such as bursting bubbles, colors of soap films, soap film models, modeling the atom with soap bubbles, and more.

Stevens, Peter S., **Patterns in Nature**, Little, Brown and Co., 1974.

Chapter 7 of this book examines the mathematics of soap bubbles. Well illustrated and readable.

Zubrowski, Bernie, **Bubbles**, Little, Brown and Company, 1979.

Activities with bubbles including very big bubbles, soap-film curves, geometric shapes, domes, bubble building blocks, and more. Does not give specific recipes, but encourages experimenting with making bubble solutions.

Articles

Almgren, Frederick J. Jr. and Taylor, Jean E., "*The Geometry of Soap Films and Soap Bubbles*", **Scientific American, 235**, 82 (July 1976).

A semi-technical article on the mathematics of bubbles. Well illustrated.

Katz, David A., "*Chemistry in the Toy Store*", **1988 Yearbook of Science and the Future**, **Encyclopedia Britannica, 1988**, 154.

Soap bubbles lead off this article on the science behind many toys.

Kuehner, A. L., "*Long-Lived Soap Bubbles*", **Journal of Chemical Education**, **35**, 337 (July 1958).

A recipe for making a soap that will produce soap bubbles that can last for many months in a jar or other closed environment. This recipe requires handling some hazardous material. A chemistry laboratory is required.

Strong, C. L., "*How to blow soap bubbles that last for months and even years*" in *The Amateur Scientist*, **Scientific American, 220**, 128 (May 1969).

A discussion of the work of Dr. A. V. Grosse and his long lived bubbles. A laboratory is needed to prepare some of his solutions.

Bubble Materials

Your local toy store, science and nature stores, and also Science Museum shops are resources for bubble materials. These items are seasonal, that is, any of them may not be available in your area during colder months. You will find many items such as bubble guns, bubble mowers, a bubble bee, bubble airplanes, and more. These items change from year to year. Use discretion in purchasing bubble items, most items do not make large bubbles and do not work as they are expected.

Some items that can be used to make large bubbles are:

A set of two 18 cm diameter bubble wands consisting of a large single loop and one filled with smaller loops and a small plastic pan is available under the name Mickey's (Mouse) Million Giant Bubbles, manufactured by Chemtoy Corp. A variation of that set includes a large loop filled with smaller heart shaped loops

A concentric loop for making bubbles in a bubble is available under the name Giant Bubbles, manufactured by Hedstrom

David Stein's Bubble Thing® for giant bubbles six feet long or larger. It should come with Cassidy's **The Unbelievable Bubble Book.**

The Bubble Trumpet which is a long narrow funnel. Good for making a chain or medium-large bubbles.

Kubic Bubbles. Some years ago, this author obtained a set of plastic coated, wire bubble frames consisting of a cube, tetrahedron, octahedron, triangular prism, and helix (screw thread), sold under the name Kubic Bubbles, from The Exploratorium Store in San Francisco, CA. This well made and sturdy set is no longer available as the manufacturer ran out of cubic frames, however, the remaining set of four plastic coated wire frames: the tetrahedron, octahedron, triangular prism, and helix (no cubic frame), can be obtained by special order from Cochranes of Oxford Ltd., Leafield, Witney, Oxon, 0X29 9NY, England or contact them on the internet at www.cochranes.co.uk

Currently, the Kubic Bubbles set consisting of plastic tubes and angle fittings which allows one to construct four geometric bubble frames is available from some scientific supply companies under the name Kubic Bubble or from Cochranes of Oxford Ltd as listed above.

Zome System, a set of spherical connectors, called nodes, and connecting rods that allow one to construct almost any geometric shaped frame. Find local stores or order direct, and download lesson plans for teachers and families on the company web site: www.zomesystem.com

Appendix 1

Preparation of Long Lived Soap Bubbles

The preparation of Sodium 9,10-Dibromostearate Solution, a modification of the preparation by A. L. Kuehner, Bishop's University, Lennoxville, Quebec, Canada, which appeared in the **Journal of Chemical Education**, **35**, 337 (July 1958).

Kuener stated that bubbles made from the sodium 9,10-dibromostearate are superior to those made from sodium oleate. Bubbles, 20 cm. in diameter, made from a 4% solution of sodium 9,10-dibromostearate, containing an equal volume of glycerol, had an average life of 102 minutes in the open air, the longest-lived bubble lasting for 152 minutes. By comparison, 20-cm. diameter bubbles blown from a 3% solution of purified sodium oleate, also containing an equal volume of glycerol, had an average life of only 36 minutes. The sodium oleate was made from the same purified oleic acid that was used to prepare the 9,10-dibromostearic acid and its sodium salt. A 4% solution of the dibromo soap was compared to a 3% sodium oleate solution so as to have approximately equal molar concentrations of soap in each case.

In this work the relative stability of bubbles was determined by pouring soap solution, containing an equal volume of glycerol, into a 10-cm. diameter Petri dish and blowing a bubble 20 cm. in diameter, allowing it to rest on the rim of the dish. The bubbles were not protected in any way. The lifetime of the bubble was recorded as the average of the life of ten or more individual bubbles.

In bubbles made with sodium 9,10-dibromostearate solutions the surface monolayers seem to be in equilibrium with the solution in the interior of the film since a few moments after being blown the bubbles no longer show any turbulent motion of interference colors. That the film is still liquid is evidenced by the slow appearance of horizontal concentric rings of interference colors at the bottom of the bubble.

Very interesting bubbles consisting entirely of black film, a film which is too thin to give colors by interference, may be made using the sodium 9,10-dibromostearate solution. A layer of water to maintain a high humidity is placed in the bottom of a large jar and a Petri dish containing the soap solution is mounted above the water. A bubble which rests on the rim of the dish is then blown inside the jar and the jar covered. After several days of drainage a circular patch of black film appears at the top of the bubble. This gradually increases in size until the entire bubble is black. When completely drained, the thickness of the bubble film approximates the thickness of the two surface monolayers. There is a large variation in the life of such protected bubbles since, being so thin, they are very fragile. Nevertheless, one such bubble lasted for 48 days.

Safety Precautions
This procedure must be performed in a fume hood in a chemistry laboratory.

Safety goggles must be worn during this procedure.

Bromine is toxic by inhalation and causes severe burns. Bromine should always be handled in the fume hood. Gloves should be worn.

Procedure

In his procedure, Kuehner started with the purification of oleic acid, his starting material. The author found that fresh oleic acid was pure enough that this step could be eliminated.

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Preparation of 9,10-Dibromostearic Acid

In a fume hood, 28.2 g of oleic acid was placed in a beaker and cooled in a mixture of ice and salt and stirred using a motor drive stirrer. Using a fine-tipped dropper, 16 g. of bromine was then added slowly maintaining a temperature below 11°C.

The dibromo acid, formed from the reaction, was then dissolved in a mixture of 80 ml. acetone and 5 ml. of distilled water and chilled, covered, in a freezer, to about -20°C for six hours or overnight. A small amount of solid acids which crystallized was removed by filtration.

The acetone solution was then poured into hot distilled water, transferred to a separatory funnel, and the heavy dibromo acid was separated. The dibromo acid was washed twice with hot distilled water. After the final separation the acid was warmed and swept free of acetone and water with a stream of helium. About 40 g of 9,10-dibromostearic acid was obtained.

NOTE: During all of these operations great care was taken to avoid contamination with grease. All equipment was washed with acetone before use. No stopcock grease was used to lubricate the stoppers of the separatory funnel.

Preparation of Sodium 9,10-Dibromostearate Solution

Twenty grams of 9,10-dibromostearic acid and 470 mL of distilled water were placed in a beaker, fitted with pH electrodes, on a magnetic stirrer. 3 M sodium hydroxide solution was added slowly forming a thick suspension as the acid reacted. Taking care to maintain a pH of 10 or below, additional sodium hydroxide was added until all of the solid dissolved. The solution was covered and allowed to stand for a day to permit any small amount of unreacted acid to become thoroughly dispersed.

The pH of the solution was checked the following day and adjusted to a pH of 10–10.1 by adding 1 M sodium hydroxide dropwise. The final clear solution contained approximately 4% sodium 9,10-dibromostearate. (Note: Kuehner cautions that excess alkali must be avoided.)

Just before use one volume of glycerol was added to an equal volume of soap solution.

Note: Sodium oleate solution was prepared directly from oleic acid in the same way. The solution became clear at pH 9.9-10.

Appendix 2

Preparation of Polyvinyl Alcohol Solutions

To prepare 500 mL of solution, 20.0 g of polyvinyl alcohol (Flinn Scientific catalog no. P1053 or P1045) was mixed with 480 mL room temperature distilled water in a 600 mL or larger glass beaker or heat-proof container. The mixture was stirred to disperse the solid polyvinyl alcohol.

The beaker was placed in a microwave oven and heated at full power for 1 minute. The beakere was removed and the solution was stirred.

Caution:

> During the heating process, the bottle will become hot. Wear gloves or oven mitts when handling the hot container.

The beaker and contents were heated for another 1 minute at full power. The beaker was removed and the solution was stirred..

Heating cycles were reduced to 15 second intervals. After each heating, the solution was stirred. This procedure was repeated until a clear solution was obtained.

The solution was poured into a plastic bottle and allowed to cool. The bottle cap was placed on top of the bottle, but was not screwed in place until the solution was at room temperature.

A 6% polyvinyl alcohol solution was prepared by dispersing 30.0 g of polyvinyl alcohol in 470 mL of water and heated in the same manner as the 4% solution, above.

A 8% polyvinyl alcohol solution was prepared by dispersing 40.0 g of polyvinyl alcohol in 460 mL of water and heated in the same manner as the 4% solution, above.