International Journal on Hands-on Science [ISSN (print): 1646-8937; (online): 1646-8945]
Received October 27, 2008; Accepted November 24, 2008.
The Hands-on Science Network' 2008

Itinerant Museum of Chemistry History
The Soap

Juliana Mesquita Contarini, Walter Ruggeri Waldman
LCQUI - CCT / Universidade Estadual do Norte Fluminense Darcy Ribeiro
julianacontarini@hotmail.com capiwalter@gmail.com

Abstract. *Due to the lack of activities aiming the increase in interest in science in the North Fluminense region, the Itinerant Museum of Chemistry' History was created. The Museum's goal is to promote experimental chemistry among students and public school teachers through the adaptation of classical experiments in the history of science and technology. In the specific case of soap, the experiments were developed seeking safety and low-cost materials. This work describes experiments for soap formation using different kinds of fat, and the use of the produced soap in experiments that demonstrate surfactants properties, such as water superficial tension and emulsification.*

Keywords. Itinerant museums, Chemistry' History, Soap, Science Education.

1. Introduction

According to an international evaluation of quality in science teaching to 15 years-old students performed by Programme for International Student Assessment (PISA), Brazil is in one of the last positions in comparison with more developed countries. This fact might be explained by Brazil's great socioeconomic inequality. Nevertheless, this situation is particularly concerning when considering countries of the same region and economic reality, e.g. Argentina, Uruguay and Chile [1]. Brazil's ranking in PISA 2007 is a result of the lack of investments in science teaching in addition to the lack of adequate structure for science laboratories in educational institutions.

Another research was promoted by the Ministry of Science and Technology (*MCT* in Portuguese) in 2007 [2]. This study also involved the Brazilian Academy of Science, FIOCRUZ Museum of Life, FAPESP and Unicamp's Laboratory of Advanced Studies in Journalism. The study showed preoccupying results regarding the public perception of science:

- 58% of the interviewees have little or no interest in science and technology (37% of them said this was mainly due to the fact that they do not understand it);
- 73% of the search little or no information on science and technology (32% of them said this was mainly due to the fact that they do not understand it);
- only 4% of the interviewees visited a museum of science in the last year;
- from the 96% that did not visit museums of science in the last year, 47% said this was mainly due to the museums' location (35% declared there were no museums of science in their area and 12% declared that the museums are very far).

Nowadays, museums and centers of sciences are not recognized as a place of scientific production anymore [3]. Instead, they are a place of representation of science and a link between society and scientific production [4].

Some authors have been emphasizing the importance of visits to spaces of science as a means to develop a more critical perception of the world.

"*Museums of science and technology enable visitors to look at the world in a different way after the visit. They see things that they have never seen and, eventually, make things that they have never made because they thought they were not able. The Centers and Museums of Science's goals are raising awareness to scientific culture; avoiding possible "anti-scientific" resistance and encouraging attitudes and processes of science, especially curiosity and critical thinking.*" [5]

Aiming to help the reversion of science education's current situation and to establish interactions between society and science, the Itinerant Museum of Chemistry History was created in the North Fluminense region, promoting strategies of improvement in Chemistry teaching.

Based on MCT research's results, we decided for the museum's mobility in order to assist the several North Fluminense regions and to minimize the problem of museums' distance.

Another objective of the project is to improve students and teachers' knowledge on History of

International Journal on Hands-on Science [ISSN (print): 1646-8937; (online): 1646-8945]
Received October 27, 2008; Accepted November 24, 2008.
The Hands-on Science Network' 2008

Sciences by developing specific activities on the topic. The activities for teachers will be trainings that are being implemented at the Regional Coordination of Education of North Fluminense Region. The training's aim is the actual application of Science History in the teaching of sciences. The activities for students will be presentations of experiments related to the History of Chemistry, focusing on technologies that are part of students' everyday life. Some research has been made on this area, namely the application of History of Science when teaching Electrochemistry topics (e.g. pile) presented positive results favoring the learning and increasing students' interest during classes [6].The Itinerant Museum of Chemistry History nowadays works with four topics that are related to classic experiments in the History of Science and Technology. These topics are part of students' everyday life and offer the possibility of approaching current Chemistry topics in high school. The topics are: candle, beer, soap and food conservation. The four topics were presented in *Scientiarum Historia* - 1st Congress of History of Sciences and Techniques and Epistemology.

1.1 Soap

In this study, the topic soap will be developed with experiments based on its history. The preparation of experiments will require materials such as ashes and soda. Support texts will be made to explain the chemistry involved. These texts will be used by students and by high school teachers who do not hold a Bachelor degree in Chemistry (in Brazil, only 13% of public school Chemistry teachers have Bachelor's degree in Chemistry) [7].

Soap is a common topic in Chemistry lectures as it is approached several times in high school's curriculum, i.e. organic chemistry, carbon chain's nature, saponification reactions and intermolecular interactions.

In this article, experiments will be developed in order to help discussions regarding water superficial tension, formation of surfactant monolayer on water's surface and emulsion agents.

1.1.1. Soap in health

Soap has a simple production process, which has happened since ancient times. It is worth to remark that changes in soap production contributed to human being's evolution in a direct way. Today it is practically impossible to imagine life without soap or similar products. When somebody from a tropical country does not take a shower one day, it is easily noticed by our sense of smell. It is important to remind that that bad smell that we feel is human being's characteristic smell (that we hide with perfumes of soap and of deodorant that we use everyday).

Baths as hygiene practice and health of the body only happened in the 19th century, when science identified a series of diseases [8].

1.1.2. Reactions

In the most primitive way of making soap, the basic reagents were animal fat (for instance, ox tallow) and plant ashes. In animal fat there are several glicerides that, in alkaline environment, can be decomposed in glicerol and soap. The abundant alkaline environment in antiquity was found in plant ashes, i.e. the sodium and potassium carbonates.

Figure 1 illustrates a saponification reaction.

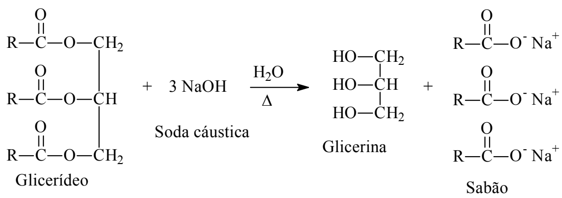

Figure 1: Representation of saponification reaction.

The alkaline hydrolisis of glicerides is called saponification reaction. Depending on the alkali used in this production, different types of soaps are obtained. When the reaction involves sodium hydroxide, or sodium carbonate, harder soaps are produced. If the reaction involves potassium hydroxide or potassium carbonate, the resulting soap is softer.

1.1.3. Soap chemical structure and properties

Soap has two different characteristics in their molecular structure: great apolar hydrocarbonic groups and a polar extremity (Figure 2).

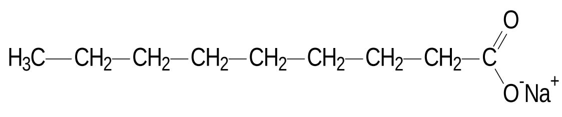

Figure 2: Representation of a soap molecule.

The polar extremity can interact with water (also polar) and the hydrocarbonic chain interacts with the fat (also apolar).

International Journal on Hands-on Science [ISSN (print): 1646-8937; (online): 1646-8945]
Received October 27, 2008; Accepted November 24, 2008.

1.1.4. Soap as a cleaning agent

Water surface behaves as an elastic film. This property of liquids is called superficial tension, and it happens due to the attracting forces among the internal molecules of a liquid and the molecules of the surface. Soap reduces the water's superficial tension, which is why soap is called a surfactant agent.

Soap has the property of concentrating oil particles in micelles, i.e. microscopic droplets of fat involved by soap molecules. Micelles are self-organized systems of soap molecules, or surfactants, and they have the following shape (Figure 3).

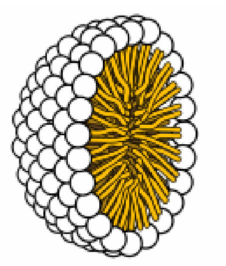

Figure 3: Representation of a micelle system.

In a micellar structure, the apolar part of soap molecules is guided to the interior of the micelle (interacting with the fat), and the polar part is guided outside the micelle, interacting with water, as shown on Figure 3.

The micelles stay dispersed in water generating an oil emulsion. This happens because their coagulation is avoided by electronic repulsion.

2. Potash

The delay in industrial and scientific development in Brazil during colonial period was mainly due to D. Maria I, who prohibited manufacture activities in the colony in 1785. In 1808, the Portuguese royalty migrated to Brazil and finally some actions to stimulate technology, labor education and, consequently, scientific thought were undertaken.

In the 18th century, during the period when modern Chemistry appeared, Frei Jose Mariano de Conceição Veloso translated some books about industrial activities to Portuguese. Veloso was devoted to Botany, leading the first botanical expedition (1779-1790) through the interior of Rio de Janeiro state, being considered one of the main names of science and technology of the Portuguese empire in the end of the 18th century and beginning of the 19th century. Veloso wrote books that helped the beginning industry, agriculture and natural history in Brazil. Veloso also described around four hundred new species of Brazilian plants.

In Brazil, one of the first written registrations related to soap was a book written by Veloso in 1798. The book's main subject was large-scale production of potash, one of the main ingredients of soap. The book "*Alographia dos álcalis fixos vegetais ou potassa, mineral ou soda e dos seus nitratos, segundo as melhores memórias estrangeiras, Que se tem escripto a este assunto parte primeira*" described the species of Brazilian plants which are rich in potassium.

Veloso had the assignment of promoting potash industry in Brazil. Potash was very significant for the beginning industry because it was used in the production of several products, such as fabrics, glass, paper, sugar, medicines and dyes. On Veloso's book, there are illustrations indicating plans for the construction of potash factories, that, when in operation, would yield profits for Portugal. The book also gives instructions to those who decided to set up potash factories in Brazil.

Until half of the 19th century, potash and soda were obtained from combustion of certain types of plants. After that, the practice disappeared with the exploration of Stassfurt's mineral deposits in Germany in 1861. With Leblanc's process, industrial production of sodium carbonate in the beginning of the 19th century [9].

3. Experiments

3.1. Soap preparation varying the fat type

Soap preparation was tested with varying types of fat, which showed that several different products can be obtained depending on the type of fat used as a reagent.

The different fat types were obtained in different ways. Some were bought in trades, such as ox tallow from slaughterhouses and soy oil from supermarkets. Others were extracted during the preparation of meals, such as chicken fat, obtained by separating the skin from the fat during its cleaning, and rib fat, obtained after the rib cooking.

To guarantee that all fats were in the same conditions, the reaction began with warm fat so that all of them were in liquid state (at room temperature, rib fat and ox tallow are in the solid

International Journal on Hands-on Science [ISSN (print): 1646-8937; (online): 1646-8945]
Received October 27, 2008; Accepted November 24, 2008.

state). In a beaker, twenty milliliters of warm fat were added. Afterwards, five grams of soda (bought at a construction store) were added. The mixture was slowly stirred for thirty minutes in a heating plate, at 100 °C. After the soap cooling, three different products were obtained (Figure 4).

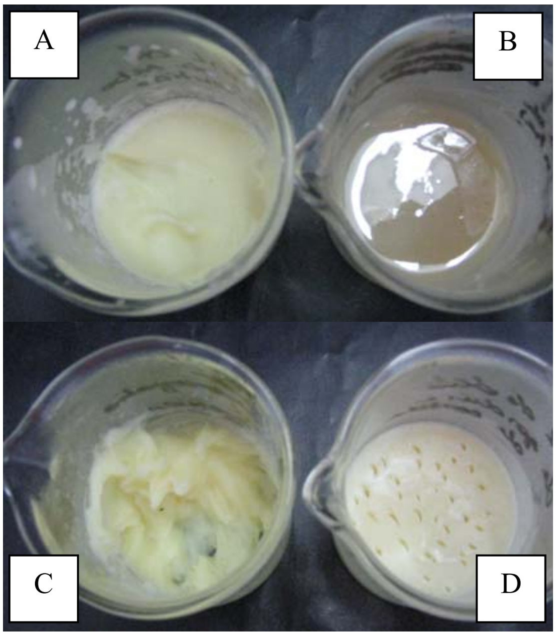

Figure 4: Soap made from several kinds of fat. A) ox tallow; B) soy oil; C) chicken fat and D) ox rib fat.

The resulting soap presented different properties. The order of hardness was (from the hardest to the least hard): ox tallow, rib fat, chicken fat and soy oil. This practice demonstrates that the various kinds of fat's different properties (i.e. insaturation level, glycerin concentration and chain size) influence the final product's physical properties. It is also possible to obtain soaps with intermediate characteristics, mixing different fat types.

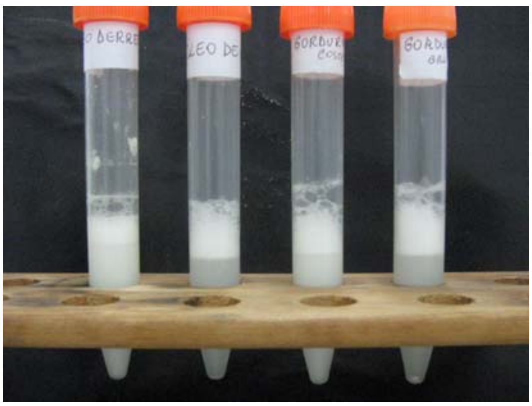

Figure 5: Samples of soap foam from different kinds of soap, just shaken. From left to right: ox tallow, soy oil, ox rib fat and chicken fat.

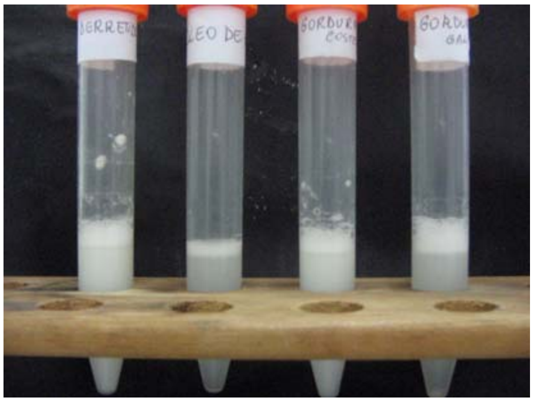

Figure 6: Samples of soap foam from different kinds of soap, one hour after the shaking. From left to right: ox tallow, soy oil, ox rib fat and chicken fat.

With the aim of characterizing the foaming capacity of each piece of soap obtained, we made a quantitative comparison with water in test tubes. 0,1 grams of different pieces of soap were mixed in 5 ml of water. The resulting foam formed on the different pieces of soap is shown on Figure **5**.

It is possible to observe that there is no significant difference in the amount of foam on different soap types. After one hour of rest, different stabilities of foam were observed (Figure 6). The foam from soy oil soap is less stable than the others.

This kind of practice, where reagent can be varied using materials from everyday life (i.e. the several fat types and different types of vegetable oils) and where the different products obtained are predictable and verifiable, stimulates the raising of students' scientific curiosity.

3.2. Influence of water hardness in efficiency of the soap

This experiment was developed to approach the influence of metallic cations, namely calcium and magnesium in soap's action. Different samples containing hard water and soap were analyzed, observing the variation in the amount of foam in function of Ca^{2+} concentration.

Water's hardness is defined in function of calcium and magnesium concentration. Hard water prevents foam formation when soap is used [10]. Water hardness is a regional factor, because the calcium and magnesium ions concentration depends on the type of rock, e.g. calcareous rocks [11].

This kind of effect occurs because Ca^{2+} and Mg^{2+} ions interact with soap's carboxilate, generating an insoluble substance before foam

International Journal on Hands-on Science [ISSN (print): 1646-8937; (online): 1646-8945]
Received October 27, 2008; Accepted November 24, 2008.

formation. A common problem involving hard water is the formation of insoluble deposits in water pipes and kettles [10].

In the hard water experiment, whitewash (used in constructions), plastic bottles, commercial detergent and coffee filter were used. Thirty grams of whitewash were added to 500 milliliters of water. This mixture was stirred and left to rest, decanting. In order to remove suspended impurities, the mixture was filtered twice using paper filter. The saturated and filtered solution was diluted several times in the following way: 250 mL of saturated solution was mixed with the same amount of water, diluting the solution's concentration in 50%. 250 mL of this solution was separated for the experiment and the other 250 mL were diluted again in 250 mL of water. This procedure was repeated 7 times, producing solutions with concentrations of around 0,8% of the original solution (Table 1).

Table 1: Solutions used in the hard water experiment. All solutions have 20 drops of detergent.

Solutions	Ca^{2+} concentrations
1	Saturated solution
2	50,0% of saturated solution
3	25,0% of saturated solution
4	12,5% of saturated solution
5	6,3% of saturated solution
6	3,2% of saturated solution
7	1,6% of saturated solution
8	0,8% of saturated solution
9	Water

3.2.2. Results and Discussion

By reducing the concentration of whitewash, an increase in the foam column was observed, as illustrated on Figure 7.

Figure 7: Picture of solutions 1, 2, 7, 8 and 9 immediately after agitation.

Four hours after agitation, two facts could be observed: 1) all foam formations are stable and 2) less foam is generated in function of Ca^{2+} concentration (Figure 8).

Figure 8: Picture of the solutions 1, 2, 7, 8 and 9 six hours after the agitation.

The metallic ions responsible for water hardness react with soap, precipitating the carboxilates that consume the soap (Figure 9).

$$Ca^{2+} + 2\ CH_3(CH_2)_{16}COO^- \rightarrow Ca(C_{18}H_{35}O_2)_{2(s)}$$

Figure 9: Representation of the formation of $Ca(HCO_3)_2$.

3.3 Lava Lamp

A mixture of water and oil was used in a proportion of 1:3 (water:oil). An effervescent pill was added to generate an ascending effect and thus, the visual effect is similar to a lava lamp. A double of this system was made and, having the two bottles in front of students, we added soap to the aqueous environment in only one of the two bottles. The result illustrates, with interesting visual appeal, the influence of detergent in emulsion formation.

The materials utilized in the experiment were kitchen oil, potassium permanganate, 600mL plastic bottles, effervescent antacid, water and a syringe adapted with a hose. The solution contains a tip of spatula of $KMnO_4$ in 200 milliliters of water. It is important to remark that permanganate is only used in this experiment due to its appealing color. Another colored substance could be used, if more easily available.

One hundred milliliters of the permanganate solution was added in each bottle. Afterwards, 300 milliliters of oil were added to each. In one of the bottles, some millimeters of a solution of detergent (15 ml in 85 ml of water), was added in aqueous phase with a syringe coupled to a fine

hose (

Figure 10A).

Finally, a tablet of effervescent antacid was simultaneously added to both bottles, and the differences between the two bottles could be analyzed. The bottles' scheme is represented in

Figure 10.

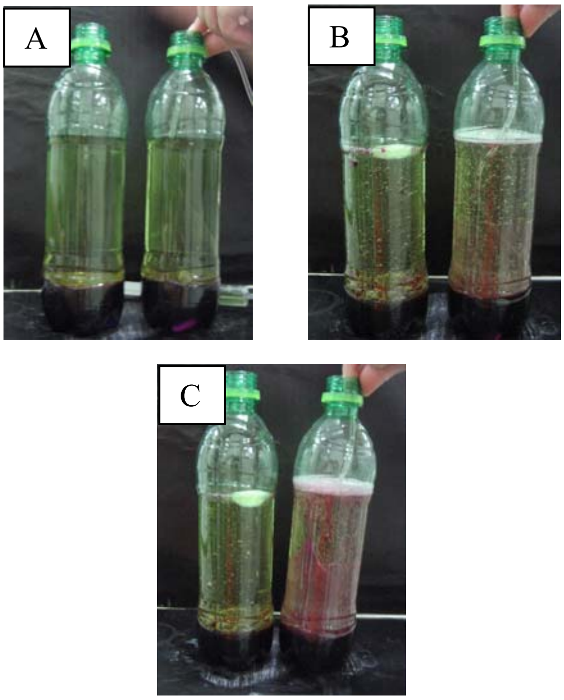

Figure 10: The bottles in different moments of the experiment. A) Before the addition of the effervescent tablet; B) just after its addition; and C) after the emulsion formation.

The effervescent tablet is mainly made of sodium bicarbonate, which reacts with water to form sodium hydroxide and carbonic acid, (an unstable acid that easily decomposes to H_2O and CO_2).

In both bottles, the formation of CO_2 bubbles was observed due to the effervescent tablet's addition. In the bottle without surfactant, the CO_2 bubbles carried the permanganate solution. After coming to the oil's surface, the permanganate solution went down due to its higher density. This ascending-descending movement resembles the functioning of a lava lamp.

In the bottle where detergent had been added in the aqueous phase, there was an emulsion

Received October 27, 2008; Accepted November 24, 2008.

formation of the system permanganate-oil

(**Figure 10**C), and foam formation during reaction. Both effects are due to the ascension of CO_2 bubbles carrying portions of water. After the reaction, the foam remained on surface.

The ascension of water bubbles in the bottle without detergent was still observed after the end of effervescence. An interesting activity is to visually follow one of these water bubbles coupled with remaining bubbles of gas. Halfway to the surface, some gas bubbles are detached from the water bubbles. The interruption in the ascending motion and the fact that they go down illustrate the density concept.

4. Conclusion

From the experience with high school visits of the Itinerant Museum of Chemistry History, we learn that dynamic experiments, i.e. the lava lamp, have an immediate impact on students' reaction. Moreover, experiments such as soap preparation and hard water encourage students to reproduce them due to their flexibility and easy execution. Thus, the students are encouraged to try them more than once, with variations in the conditions. All experiments described here stimulate students' interest in experimental practice and promote the association of everyday life experiences with scientific concepts approached in classes.

5. Acknowledgements

The authors thank UENF for Juliana Contarini's fellowship and Prof. Fernando Luna for the access to papers related to the subjects approached in this study. The authors are also thankful to Roberta Gregoli for the help with translation.

6. References

[1] http://www.estadao.com.br/ext/especiais/2007/11/oecd.pdf [01/06/2008]
[2] http://www.mct.gov.br/index.php/content/view/50875.html [07/06/2008]
[3] Lopes, Maria Margaret. O Brasil Descobre a Pesquisa Científica: os museus e as ciências naturais do século XIX. São Paulo: HUCITEC, 1997
[4] Rodari P, Merzagora M. The role of science centres and museums in the dialogue between science and society. Journal of Science Communication, 6 (2) June 2007, 1-2
[5] Gil, F.B., Lourenço, C.M. Que ganhamos hoje em levar os nossos alunos a um museu. Comunicar Ciência. 3(1999)4-5.
[6] 46º Congresso Brasileiro de Química [07/18/2008] http://www.abq.org.br/cbq/2006/trabalhos2006/6/335-503-6-T1.htm)
[7] Ruiz A.I., Ramos M.N., Hingel M. Escassez de Professores no Ensino Médio: Soluções Emergenciais e Estruturais. [06/07/2008] http://portal.mec.gov.br/cne/arquivos/pdf/escassez1.pdf
[8] Le Couteur, Penny, Burreson J. Os botões de Napoleão: as 17 moléculas que mudaram a história; translated by Maria Luiza X. de A. Borges. Editora Jorge Zahar. Rio de Janeiro: 2006. Cap. 1.
[9] Luna F. The production of Potash from plants in colonial Brazil as described in Fray Conceição Veloso's *Alographia dos Alkalis*… Química Nova, accepted for publication.
[10] Lee JD. Quimica Inorgânica não tão Concisa, Editora Edgard Blücher translated from 5th Edition, chapter 1.
[11] Mol GS, Barbosa AB, Silva RR. Água Dura em Sabão mole. Química Nova na Escola 1995. 1995;2:32-33