

2007

Sol-Gel Technology in Enhancing the Filtration of Semi-Volatile Organic Compounds

David T. Nguyen

Georgia College & State University

Jennie Ash

Georgia College & State University

Chastity Ellison

Georgia College & State University

Follow this and additional works at: <https://kb.gcsu.edu/thecorinthian>

 Part of the [Chemistry Commons](#), and the [Physics Commons](#)

Recommended Citation

Nguyen, David T.; Ash, Jennie; and Ellison, Chastity (2007) "Sol-Gel Technology in Enhancing the Filtration of Semi-Volatile Organic Compounds," *The Corinthian*: Vol. 8 , Article 19.

Available at: <https://kb.gcsu.edu/thecorinthian/vol8/iss1/19>

This Article is brought to you for free and open access by Knowledge Box. It has been accepted for inclusion in The Corinthian by an authorized editor of Knowledge Box.

Sol-Gel Technology in Enhancing the Filtration of Semi-Volatile Organic Compounds

*David T. Nguyen
Jennie Ash
Chastity Ellison*

*Dr. Catrena H. Lisse
Faculty Sponsor*

ABSTRACT

For the past several years, the field of sol-gel technology has undergone remarkable growth in areas ranging from micro-fibers to chemical sensors. Incorporating an organic phase into the colloidal mixture via pre- or post-doping can modify sol-gels, and manipulation of the size of the pores can be used in developing 'eco-friendly' water filters, particularly for filtering semi-volatile organic compounds in water. In this research project, various forms of sol-gels were made to see which is more efficient for certain semi-volatile chemicals that can be found in diverse sources of water. Organically modified silicates and different structurally sound sol-gels were made to determine which type of sol-gel material provides the most effective water filter.

INTRODUCTION

History of sol-gels

Sol-gels have been investigated for many years; however, it was almost a century before information about sol-gels became important in areas other than chemistry. In the 1840's, scientists such as Tyndall, Schulze, Becquerel, Faraday, and Graham began studying the physical characteristics of colloids, and Ebelmen synthesized silicone alkoxides from alcohol and silicon tetrachloride. The silicon alkoxides gelled with adequate time under atmospheric pressure. "In 1876, Troost and Hauterfeuille made hydrolysed derivatives of silicon alkoxides¹." Grimaux synthesized silicic acid sols from tetraethoxysilane in 1884. In the early 1900's, W.A. Patrick began the process of drying the silica gels at temperatures around 700°C. Patrick then began the

study of catalysts by doping the sol-gels with metal salts¹. In the 1930's alkoxides found a practical use as an oxide film for a German glass company. In 1932, Kistler developed a method of supercritical drying of the sol-gels².

Types of sol-gels

Sol-gels can be doped with many different compounds due to their chemical versatility. Doping is the process of adding another compound during the mixing process. These compounds become entrapped in the complex porous structure of the sol-gel. Four main factors determine which dopants will be entrapped the best: the dopant's size, the pore size distribution of the sol-gel, the stability of the sol-gel's matrix, and the porosity of the sol-gel. Dopants include organic materials, metal oxides, inorganic materials, and many more compounds. The doped sol-gels have different properties and applications than regular sol-gels. Doped sol-gels can be used as optical materials for photochromism, photoluminescence, and photochemical hole burning because the organic materials can be captured in the final glass¹.

Aging of sol-gels

After the synthesis of the sol-gels, careful attention must be given to the aging process of the sol-gels. Many changes occur during the aging of a sol-gel. Polymerization of Si-O-Si chains is forming the matrix of the sol-gel. The solution takes on solid-like properties due to the evaporation of the water or other solvents used when preparing the sol-gels. As the sol-gel dries, there is a size reduction equal to the amount of liquid that evaporates. Although much of the liquid evaporates, a small portion gets caught in the interior pores of the sol-gel². During the drying process, it is common for a sol-gel to fracture under the stress. Supercritical drying, which can stop the sol-gel from cracking, is the process of exchanging the water for alcohol. Then, the alcohol is removed under super-critical conditions¹. The aging of a sol-gel is a complex process that can usually be controlled by pressure, temperature, or pH.

Applications of sol-gels

The applications of sol-gels are endless because they are so versatile. Sol-gels can be used in many forms including films, powders, monoliths, and fibers. Sol-gel films can be used as a coating on glass in order to reflect

light, an electronic coating to reduce static electricity², and an antibacterial film for orthopedic implants³. Catalysts and abrasives can be made from sol-gels in a powder form. The monoliths can be used as filtration devices or lenses, and optical fibers can be created because sol-gels can be drawn into fibers².

THE EXPERIMENT

MATERIALS

Reagents are as follows: TMOS (Alrich, Milwaukee, WI, 99+%), methanol (Alrich, reagent grade), Hydrochloric acid (Alrich, reagent grade), Cupric Acetate (Alrich, reagent grade), Cobalt Acetate (Alrich, reagent grade), Sodium Acetate (Alrich, reagent grade), TeOS (Alrich, Milwaukee, WI, 99+%), Demethoxydimethylsilane (Alrich, Milwaukee, WI, 99+%).

Acid-catalyzed wet silica gels were prepared by mixing 4.28 mL of TMOS, 2.24 mL of methanol, 0.69 mL of water, and 3.10 mL of 0.1 M HCl in a plastic vial overnight to ensure complete mixing. After mixing, cast the solution from the vial into test tubes to allow to gel (which occurs within 1-2 weeks). For all gels, carry out aging under ambient conditions until the gels pulled away from the walls of the test tubes. Gels made are TMOS, TMOS doped with cupric acetate, TMOS doped with cobalt acetate, TMOS doped with sodium acetate, and ormosils.

INSTRUMENTATION/FILTRATION PROCESS

For the supercritically dried gels, separate each type into monolith and crushed gels. A specifically cut piece of high grade white filter paper is placed into the bottom of the stainless steel cell (made by Thomas Noël and Dr. Ken McGill, GC&SU Machine Shop). Place a monolith or crushed gel into the stainless steel cell. Pour two 5 mL portions of a 25 ppm solution of *m*-nitroaniline in water into the stainless steel cell to filter. Capture the filtrate under the steel cell in a plastic vial. Keep the vial in dark until the solution ready is to be analyzed. Repeat filter for every monolith and crushed gel.

ANALYSIS

The filtered solution is analyzed using a Shimadzu UV/Vis. Analysis is to show the amount of the semi-volatile compound is filtered from the solution by each gel. Each sample is placed into a polystyrene cuvette. Scans are then run from 200 nm to 900 nm for each sample. Each graph is analyzed to show filtration of the solution.

RESULTS

Figure 1

Calibration Curve of m-Nitroaniline

Calibration Curve of m-Nitroaniline

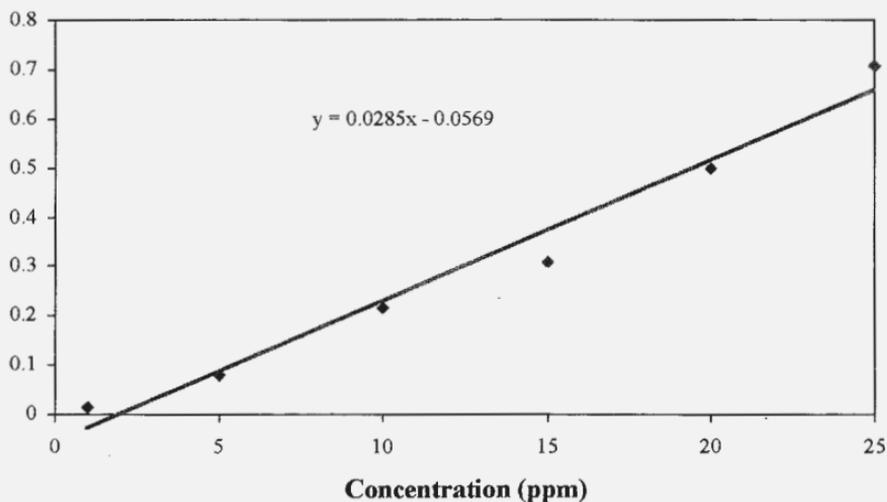


Figure 1 is a calibration curve developed after we analyzed solutions of m-nitroaniline ranging from 1 ppm to 25 ppm. We determined the remaining percent of m-nitroaniline after filtration by extrapolating data from the calibration curve.

Table 1

Extrapolation Data from the Calibration Curve

Type of Gel	% Concentration Left
TMOS crushed	87.147
Cu TMOS crushed	88.277
Co TMOS crushed	83.333
Na TMOS crushed	80.65
TMOS monolith	89.326
Cu TMOS monolith	87.927
Co TMOS monolith	89.589
Na TMOS monolith	84.339

Table 1 shows the data collected after analyzing each sample filtrate for its absorbance and comparing to that of the standard solution of *m*-nitroaniline.

Figure 2

Filtration of m-Nitroaniline

Calibration Curve of *m*-Nitroaniline

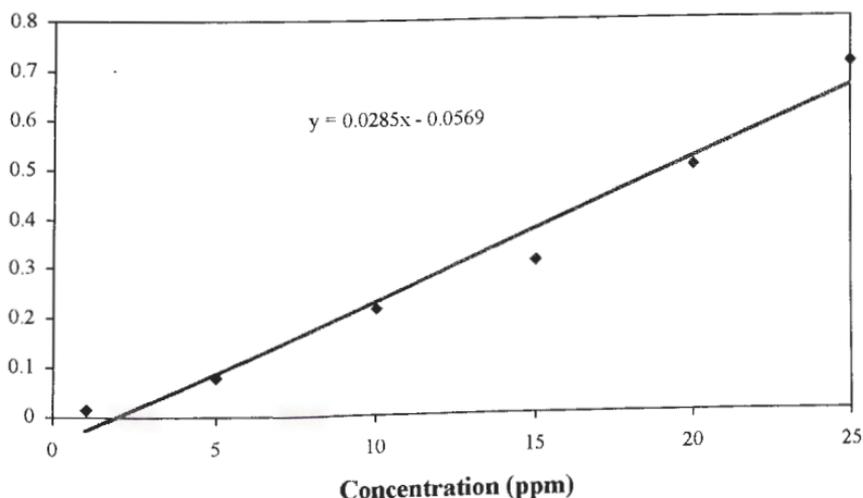


Figure 2 shows the remaining percent of m-nitroaniline is graphed as a function of the type of gel used. The pink and green bars represent the crushed and monolith sol-gels, respectively. The lower percentages indicate a better filter. This means that more of the compound was trapped in the pores of the gel.

CONCLUSION

It is shown that the crushed sol-gels filter m-nitroaniline better than the monolith gels, with the sodium acetate TMOS gels having the best filtration capabilities. Research is on-going in the continuation of making and testing various types of sol-gels. Further research might test different types of water samples containing other semi-volatile organic compounds.

ACKNOWLEDGEMENTS

This work was supported by the Department of Chemistry and Physics, Georgia College & State University. The stainless steel cell was created and provided by Thomas Noël and Dr. Ken McGill, Georgia College & State University Machine Shop. We are grateful to Dr. Rosalie A. Richards for assistance with the UV/Vis and to Dr. Jeanette K. Rice (Georgia Southern University) for original study of research conducted.

REFERENCES

- Wright, John D. and Sommerdijk, Nico A.J.M. Sol-Gel Materials Chemistry and Applications. Taylor & Francis: London. 2001.
- Brinker, C. Jeffrey and Scherer, George W. Nablo, Brian J., Rothrock, Aaron R., and Schoenfisch, Mark H. "Nitric Oxide-releasing Sol-gels as Antibacterial Coatings for Orthopedic Implants."