Water Marbles

Introduction

"Water marbles" are an aqueous polymer gel obtained from a specially designed polyacrylamide polymer. The gel exhibits interesting properties and applications because it has essentially the same refractive index as water.

Concepts

- Superabsorbent polymers
- Index of refraction
- Discrepant event

Materials (for each demonstration)

Water, distilled or deionized (DI)
Water marbles, 1 g
Balance, 0.01-g precision
Beaker, 250-mL
Beaker, 1-L
Laser pointer
Marker
Paper
Ruler
Sphere, steel
Weighing dish, large

Safety Precautions

Water marbles are considered nonhazardous. However, if ingested, they may irritate the gastrointestinal tract. Avid contact with eyes. Wear goggles whenever working with chemicals, heat or glassware in the lab. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Safety Data Sheets for additional safety, handling and disposal information.

Preparation

Dry water marbles must be soaked for several hours (overnight is best) before they reach their desired shape and consistency. *Note:* Some of the water marbles may split during this process.

Procedure

Part A. Estimating the Sphere's Radius

1. Measure the diameter (in mm) of several dry water marbles using a ruler. Record the diameter.
2. Using a balance, mass 1.00 g of dry water marbles, and have students record the exact mass.
3. Place the water marbles into a 1-L beaker.
4. Add deionized or distilled water to fill the beaker three-quarters full.
5. Let water marbles soak for several hours—overnight is best.
6. Once the water marbles are fully hydrated, tare the weighing dish and mass the water marbles. *Note:* Do not transfer water to the weighing dish, only the water marbles. If necessary, let water drain off the water marbles immediately before transfer.
7. Have students record the average mass of a hydrated water marble. Also, if desired, measure the diameters (in mm) of several other water marbles and record the average diameter.

Part B. Floating Steel Sphere

8. Gently put four whole and fully hydrated water marbles into a 250-mL beaker.

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9. Gently place four more water marbles in a layer on top of the first four water marbles to form an additional intertwining layer (see Figure 1). A third layer may be added if desired—this will float the steel ball closer to the top of the beaker.
10. Gently place a steel sphere in the center of the upper layer of the water marbles.
11. Fill the beaker with DI water to the bottom of the steel ball covering all of the water marbles. The steel sphere should appear to be floating in the water (see Figure 2).

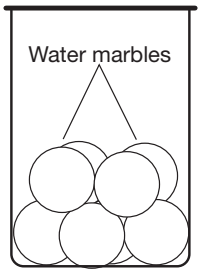


Figure 1.

Part C. Refractive Index with Laser

12. Shine a laser light through the area of the beaker containing the water marbles and water. Use paper to show the laser beam is not diffracted.
13. Cautiously remove the steel ball and set aside. Pour all water out of the beaker without removing the water marbles.
14. Shine the laser through the area of the beaker containing only the water marbles. Use paper to show the laser beam is diffracted as light passes through the polymer gel.

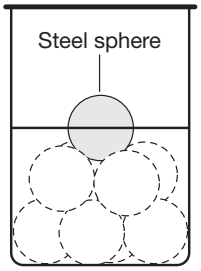


Figure 2.

Part D. Message Reader

15. Write a message, with a maximum length of 7 cm, on a piece of paper.
16. Place the beaker with water marbles on the paper.
17. Have a student volunteer try to read the message—should be unsuccessful.
18. Pour enough DI water into the beaker to cover all of the water marbles and ask the student to again read the message—the message should be easy to read.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS1 Matter and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions

Disciplinary Core Ideas: High School
HS-PS1 Matter and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions

Science and Engineering Practices
Developing and using models
Analyzing and interpereting data

Crosscutting Concepts
Cause and effect
Structure and function

Tips

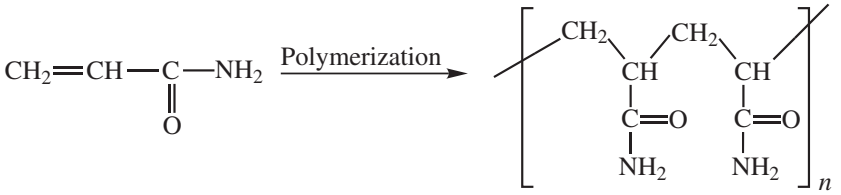
- A beaker or glass with vertical sides works best for Part B. Do not jostle the beaker or the steel sphere may drop to the bottom.
- Do not leave the steel sphere resting on the water marbles for too long. The outer coating may dissolve and the sphere may begin to rust.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Dry marbles may be stored for future use. Hydrated water marbles should be air dried and allowed to return back to their original size before storage. Depending on the temperature and humidity, this process may take several days. If disposal is desired, place the water marbles in the trash according to Flinn Suggested Disposal Method #26a.

Discussion

Water marbles and compounds like "ghost crystals" are composed of a hydrophilic (water-loving), cross-linked polymer called polyacrylamide. The polymer contains thousands of acrylamide units that have been joined together by an addition reaction (Equation 1). The numerous polar C=O and $-NH_2$ groups in polyacrylamide form strong hydrogen bonds to water molecules, and the polymer readily absorbs large amounts of water to form a polymer gel.



Acrylamide *Polyacrylamide*

Equation 1

The polyacrylamide chains in water marbles are interlaced due to the addition of a cross-linking agent during polymerization. The cross-linking agent forms covalent bonds between individual polymer chains so they are essentially "tied." The network structure is very large, and there is plenty of "empty space" for absorption of water molecules. When the dry polymer marbles are placed in water, they readily absorb water and swell to many times their original size.

Polyacrylamide and sodium polyacrylate (the material used in disposable diapers) are commercial examples of superabsorbent polymers. The main uses of polyacrylamide are in municipal and industrial water treatment—it is used as a flocculant to clarify water by increasing the rate of settling of suspended solids. "Water gel crystals" like ghost crystals and water marbles are sold commercially for use in gardening and as watering aids for indoor plants. (A copolymer of polyacrylamide is also used in the popular "Grow Beast" toys.) Polyacrylamide water marbles will absorb approximately 200 times their weight in water to form crystal-clear, gelatinous spherical solids. Because a swollen or hydrated water marble is made up almost entirely of water, its index of refraction is essentially the same as that of water, and the water marble "disappears" when placed in water. When the water marble is removed from the water, it instantly becomes visible again because the index of refraction of air is much different from that of the marble or water.

Reference

Gore, G. R. Physics Fun with Jelly Marbles. *The Physics Teacher.* **2009**, *47*, 606–607.

Water Marbles are available from Flinn Scientific, Inc.

Catalog No.	Description
AP7497	Water Marbles, 100 g
AP7429	Water Marbles—Chemical Demonstration Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.