

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

Safety Precautions

Water marbles are considered nonhazardous. However, if ingested, they may irritate the gastrointestinal tract. Avoid 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.

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).

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.

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.

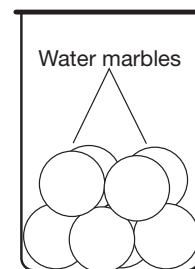


Figure 1.

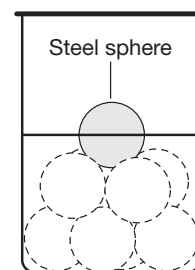


Figure 2.

Tips

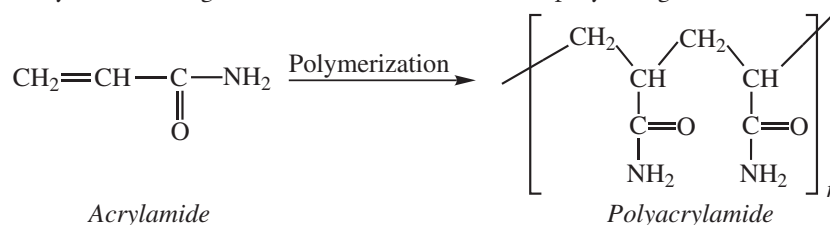
- A beaker or glass with vertical sides works best for Part B. Do not jostle the beaker or the steel sphere may drop to the bottom.
- Do not leave the steel sphere resting on the water marbles for too long. The outer coating may dissolve and the sphere may begin to rust.

Disposal

It is recommended that you consult your local school board and/or municipal regulations for proper disposal methods that may apply before proceeding.

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 –NH₂ groups in polyacrylamide form strong hydrogen bonds to water molecules, and the polymer readily absorbs large amounts of water to form a polymer gel.



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 Canada, Inc.

Catalogue No.	Description
APJ7497	Water Marbles, 100 g
APJ7429	Water Marbles—Chemical Demonstration Kit

Consult www.flinnsci.ca or your *Flinn Scientific Canada Catalogue/Reference Manual* for current prices.