# The Crystal Forest

Favorite Holiday Demonstrations

FLINN SCIENTIFIC CHEM FAX!

## Introduction

Put a new twist on crystal growing. In this class participation demonstration, students cut out and assemble miniature trees and place them in solutions of various ionic compounds. Overnight, the trees transform into a forest of snow-covered firs.

## Concepts

- Crystal formation
- Transpiration
- Capillary action

## Materials (for 30 students)

Ammonia, household, 70 mL
Bluing solution, 420 mL
Sodium chloride, NaCl, 500 g
Vegetable dyes (food coloring), red and green (optional)
Water, distilled or deionized, 420 mL
Blotting paper sheets, 30 trees, 6
Erlenmeyer flask, 1-L
Graduated cylinder, 500-mL
Graduated cylinder, 100-mL
Hot plate
Scissors, many pairs
Stirring rod
Weighing dishes, disposable, 3″ × 3″, 30

## *Safety Precautions*

*Household ammonia is slightly toxic by ingestion and inhalation; both liquid and vapor are extremely irritating especially to the eyes. Use caution when handling both bluing solution and the crystal growing solution to prevent spilling on clothes. The bluing solution will stain clothing. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Safety Data Sheets for additional safety, handling, and disposal information.*

## Preparation

1. Distribute six sheets of blotting paper with printed trees and have students cut out the 60 tree silhouettes.
2. Each student should have one set of tree silhouettes, one tree silhouette with a marked 1½″ line at the top and one with 1½″ line at the bottom (Figure 1).

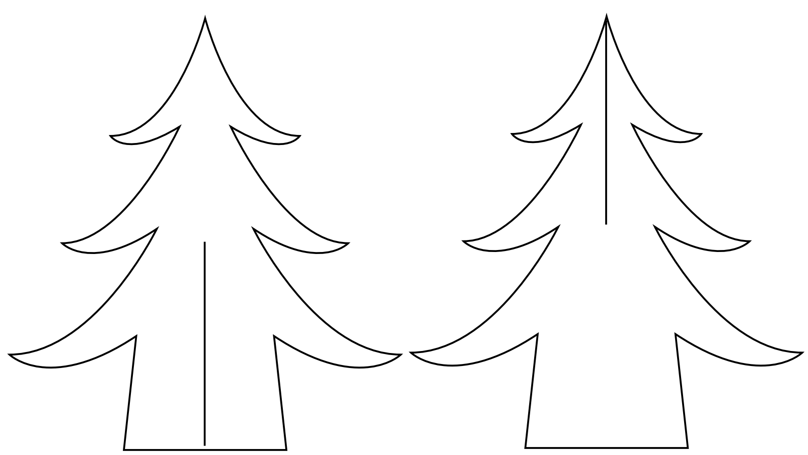

**Figure 1.**

3. Cut the 1½″ line on each tree silhouette. Make a tree by sliding the tree silhouette with a bottom cut over the tree with a top cut to form a three-dimensional tree with four sides at 90° angles (Figure 2).
4. *(Optional)* Add a drop of food coloring to the tips of each branch on the trees. This will add color to the crystals that form.

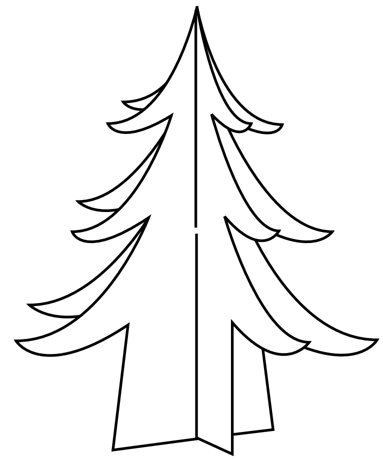

**Figure 2.**

## Procedure

1. Place the 1-L Erlenmeyer flask on the hot plate in a fume hood or a well-ventilated area.
2. Using the 500-mL graduated cylinder, measure out 420 mL of distilled or deionized water and transfer it to the 1-L Erlenmeyer flask.
3. Heat the water to just below boiling (80 °C–90 °C).
4. Weigh out 500 g of sodium chloride and slowly add the entire amount to the 1-L Erlenmeyer flask. Stir to dissolve.
5. Thoroughly mix the bluing solution by shaking the bottle with the cap securely fastened.
6. Using the 500-mL graduated cylinder, measure out 420 mL of the bluing solution and transfer it to the 1-L Erlenmeyer flask. Stir to mix.
7. Using the 100-mL graduated cylinder, measure out 70 mL of the household ammonia and add this to the 1-L Erlenmeyer flask. Stir to mix.
8. Pour 30 mL of the solution into each weighing dish.
9. Place the weighing dishes in a place where they will not be disturbed. Then, stand a tree up in each weighing dish, making sure the bottom edges are soaking in the solution. The crystals will start to form in 1–12 hours, depending on the rate of evaporation. The crystals will continue to be deposited up to 25 to 48 hours or until all the liquid has evaporated. Do not move or touch the trees once the crystals start to form. The crystals are very fragile.

## Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The trees and crystals and sodium chloride may be disposed of according to Flinn Suggested Disposal Method #26a. The bluing and ammonia solutions may be disposed of according to Flinn Suggested Disposal Method #26b.

## Tips

- *The Crystal Forest—A Chemistry Activity Kit* (Catalog No. AP6307) is available from Flinn Scientific and contains enough materials for 30 students: 450 mL of bluing solution; 75 mL of ammonia solution; 500 g of sodium chloride; 6 sheets of blotting paper; and 30 disposable weighing dishes.
- Using hot water helps the salt dissolve faster and also allows for more rapid crystal formation.
- Use proper decanting techniques to prevent spilling and possible staining by the bluing solution.
- All the sodium chloride may not dissolve. The excess can be left in the 1-L beaker.
- Because the bluing solution contains undissolved solids, be sure to thoroughly mix the bluing solution before adding it in step 4.

## Discussion

The porous blotting paper allows for both capillary action and evaporation. The solution rises through the blotting paper due to capillary action and the solvent slowly evaporates, beginning at the top edges and tips of the tree branches. As the solvent evaporates, crystals begin to form. Like tree and plant transpiration, evaporation causes more solution to be pulled up through the tree to the edges, where further evaporation leads to a buildup of more crystal deposits.

The bluing solution contains two forms of the blue pigment Prussian blue. The "soluble" form $KFe^{III}Fe^{II}(CN)_6$ is actually a stable colloidal suspension (a solid dispensed in a liquid), while the insoluble form $Fe^{III}_4[Fe^{II}(CN)_6]_3 \cdot xH_2O$ settles out of solution upon standing.

The bluing mixture is combined with an ammonia solution ($NH_3$) and a saturated solution of sodium chloride (NaCl). The fluffy white crystals that form on the branches of the trees are believed to be ammonium chloride ($NH_4Cl$) and two forms of ferrous ferrocyanide, $KNaFe^{II}Fe^{II}(CN)_6$ and $Na_4Fe^{II}_4[Fe^{II}(CN)_6]_3$. The latter two compounds are produced from the reduction of the Prussian blue by ammonia in solution.

$$KFe^{III}Fe^{II}(CN)_6 + e^- + Na^+ \rightarrow KNaFe^{II}Fe^{II}(CN)_6 \qquad \textit{Equation 1}$$

$$Fe^{III}_4[Fe^{II}(CN)_6]_3 + 4e^- + 4Na^+ \rightarrow Na_4Fe^{II}_4[Fe^{II}(CN)_6]_3 \qquad \textit{Equation 2}$$

$$2NH_3 + 6OH^- \rightarrow N_2 + 6H_2O + 6e^- \qquad \textit{Equation 3}$$

## 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
**Disciplinary Core Ideas: High School**
HS-PS1 Matter and Its Interactions
PS1.A: Structure and Properties of Matter

**Science and Engineering Practices**
Asking questions and defining problems
Planning and carrying out investigations
Constructing explanations and designing solutions

**Crosscutting Concepts**
Patterns
Cause and effect
Structure and function

## Answers to Worksheet Questions

1. Describe what happened in this demonstration.

   *Trees were cut out of blotting paper and placed in a solution of bluing solution, sodium chloride, and household ammonia. In several hours, crystals started to form on the tips of the trees. Within a couple days the tree branches were covered in thick crystals.*

2. The porous paper trees promoted both capillary action and evaporation. How might this facilitate the growth of crystals?

   *The capillary action draws the liquid up throughout the paper. The same porosity that aids capillary action also allows the liquid to evaporate. Once the solution evaporates off it causes the crystals to form. Evaporation dries the paper and allows greater uptake of solution, creating more crystals.*

3. The bluing solution contains Prussian blue in two forms, one soluble and one insoluble. The soluble form is $KFe^{III}Fe^{II}(CN)_6$, and the insoluble form is $Fe^{III}_4[Fe^{II}(CN)_6]_3$. These react with ammonia to produce $KNaFe^{II}Fe^{II}(CN)_6$ and $Na_4Fe^{II}_4[Fe^{II}(CN)_6]_3$, respectively. Has the Prussian blue been oxidized or reduced by the ammonia?

   *Both forms of the Prussian blue have been reduced by the ammonia, since the Fe(III) ions in both cases gained electrons and therefore experienced a decrease in oxidation state, becoming Fe(II) ions.*

## References

DeKorte, John M. Pocket Guide to Chemistry & Chemical Reactivity, 4th Ed. Saunders College Publishing; 1999; 295–297.

Katz, David A., *Chemistry in the Toy Store*, 5th Edition, Community College of Philadelphia, Philadelphia, PA, 1990.

McDuffie, Jr., Thomas E., and Anderson, Jacqueline. *Chemical Experiments from Daily Life.* Portland, ME: J. Weston Walch Publisher, 1980.

## Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *The Crystal Forest* activity, presented by Kathleen Dombrink, is available in *Favorite Holiday Demonstrations*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

## Materials for *The Crystal Forest* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *The Crystal Forest—A Chemistry Activity Kit* available from Flinn Scientific. Materials may also be purchased separately.

| Catalog No. | Description |
|---|---|
| AP6307 | The Crystal Forest—Chemistry Activity Kit |
| A0038 | Ammonia, Household, 64 oz |
| B0235 | Bluing Solution, Flinn, 500 mL |
| S0061 | Sodium Chloride, 500 g |
| V0003 | Food Coloring, Set of Four Colors |
| FB0678 | Blotting Paper, 10 Sheets |

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

# The Crystal Forest Worksheet

## Discussion Questions

1. Describe what happened in this demonstration.

2. The porous paper trees promoted both capillary action and evaporation. How might this facilitate the growth of crystals?

3. The bluing solution contains Prussian blue in two forms, one soluble and one insoluble. The soluble form is $KFe^{III}Fe^{II}(CN)_6$, and the insoluble form is $Fe^{III}_4[Fe^{II}(CN)_6]_3$. These react with ammonia to produce $KNaFe^{II}Fe^{II}(CN)_6$ and $Na_4Fe^{II}_4[Fe^{II}(CN)_6]_3$, respectively. Has the Prussian blue been oxidized or reduced by the ammonia?