

# Migrating Colors

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This colorful demonstration illustrates how dielectric constants and molecular polarity affect solubility.

**Abstract:** Ethyl acetate has a very low dielectric constant (6.02 [1]). Water, on the other hand, has a relatively high dielectric constant (78.54 [1]). Since ethyl acetate is incapable of effectively separating the Coulombic forces of attraction between the water molecules, these two liquids are immiscible. However when ethanol, which has a dielectric constant of intermediate value (28.0 [1]), is introduced to the system a single phase is observed. This simple demonstration illustrates the connection between dielectric constant, the polarity of molecules, intermolecular attractions, and solubility. Unlike classic “like dissolves like” demonstrations that utilize hazardous chemicals such as chlorinated solvents or alkanes, this demonstration is performed using chemicals which are commonly found in household cosmetic products. Students may be asked to make predictions, followed by observation of the demonstration. An interesting twist at the end challenges students to think beyond simple predictions. In a glass cylinder, water is added to ethyl acetate (an ingredient in many fingernail polish removers). Since these two liquids are immiscible, they form two layers. A few drops of blue food coloring are then added to the cylinder. They fall through the ethyl acetate and dissolve in the water layer, dyeing it blue. But when some ethanol is then added and the mixture is stirred, it goes into a single phase of uniform color.

[1] Robert C. Weast, ed. (1986-87) CRC Handbook of Chemistry and Physics, 67th ed, (pp. E-50 - E-51). Boca Raton, Florida: CRC Press, Inc.

## Materials:

- 500 mL glass cylinder
- long stirring rod capable of reaching the bottom of the cylinder (A piece of glass tubing works pretty well.)
- 100 mL of water
- 100 mL of ethyl acetate
- 100 mL of 95% ethanol
- commercial food coloring
- a white background (optional)

**Procedure:**

- Place the glass cylinder on the table in front of the back ground. Add 100 mL of ethyl acetate.
- Add 100 mL of water. Students will observe the water falling through the ethyl acetate to form a separate layer on the bottom of the cylinder.
- Add 2 or more drops of food color and stir. The amount of food coloring that you need to add depends on the quality and color of food coloring that you use. The students will observe the food coloring dropping through the ethyl acetate and dissolving in the aqueous layer, making it even more distinct.
- Add 100 mL of 95% ethanol and stir. The mixture forms a homogeneous, single-phase solution with the color evenly distributed throughout.

**Presentation Notes:**

This demo can be used for classes at many different levels. At the simplest level it can be used to demonstrate what we mean when we speak of solubility and miscibility. At a slightly higher level we can refer to the polarity of the solvents and the nature of the hydrogen bond. We can point out that ethanol, while capable of forming hydrogen bonds, also contains several relatively non-polar carbon-hydrogen bonds and is therefore “intermediate” in polarity between water and ethyl acetate. At an even higher level we can bring in the dielectric constant values mentioned in the abstract and talk about the charge separation issues involved when substances with different dielectric constants are mixed.

Whatever level the demo is presented at, it is a good “hook” and good pedagogy to relate the demo to the problem-solving process that commercial chemists used when developing acetone-free fingernail polish removers. So you might want to try something like the following “script”:

“Most fingernail polish removers were originally acetone-based, but acetone has such an affinity for water that it tended to dry out the skin, cuticles, and nails. Chemists found that ethyl acetate removed fingernail polish just great, and, since it was immiscible with water, it didn’t pull water out of skin, cuticles, and nails.”

*(Pour ethyl acetate into cylinder.)*

“But there are problems with pure ethyl acetate. Its vapors are very flammable and it really doesn’t smell that great. The best way to help reduce these problems is to add a non-volatile liquid to reduce the vapor pressure.”

*(A brief discussion of Raoult's Law could be inserted here if appropriate your class.)*

“The most obvious candidate is water.”

*(Add water.)*

“But the problem with this is also obvious, because, as we have mentioned already, ethyl acetate and water are immiscible. Another problem is that if I'm going to sell this stuff I've got to make it look pretty and smell good! (People seem to like that in cosmetic products.) So I want to be able to add dyes and fragrances and stuff.”

*(Add food coloring and stir.)*

“Well, what have we got here? Certainly nothing that we can put in a bottle and market! It's in two phases, like Italian dressing. People are used to shaking up their Italian dressing before they use it, but they certainly don't want to have to do that with their fingernail polish remover! What can I do to get this stuff to mix together? What if I add something that is 'in-between' in polarity? Something that is capable of hydrogen bonding like water, but not quite so polar? Something like ethanol?”

*(Add ethanol and stir.)*

“There we go. Now that's a product that I could bottle up and sell! Anybody got any old fingernail polish that needs removing?”

*(This question is a rhetorical gag. Though this mixture would probably make pretty good fingernail polish remover, it's not a good idea to let students use it. You don't want to get them in the habit of using laboratory chemicals for cosmetic purposes.)*

### **Safety:**

- Both ethanol and ethyl acetate are very flammable. The demonstration area should be kept clear of flammable materials and possible sources of ignition. An ABC fire extinguisher should be kept readily available when performing this demonstration. Use appropriate precautions when transporting and storing these substances.
- Perform this demonstration in a well-ventilated area and avoid breathing ethyl acetate fumes.
- Wear splash goggles when performing this demonstration.
- Potential health effects of ethyl acetate:
  - Inhalation can cause severe irritation of mucous membranes and upper respiratory tract. Symptoms may include burning sensation, coughing, wheezing, laryngitis, shortness of

breath, headache, nausea and vomiting. High concentrations may cause lung damage. An irritant to the nose, throat, and upper respiratory tract. Exposure to high concentrations has a narcotic effect and may cause liver and kidney damage.

- Ingestion causes irritation to the gastrointestinal tract. Symptoms may include nausea, vomiting and diarrhea.
- Skin contact causes irritation to skin. Symptoms include redness, itching, and pain. Repeated or prolonged contact with the skin has a de-fatting effect and may cause dryness, cracking, and possibly dermatitis.
- Eye contact causes irritation, redness, and pain.
- Chronic overexposure may cause anemia with leukocytosis (transient increase in the white blood cell count) and damage to the liver and kidneys.
- Persons with pre-existing skin disorders or eye problems, or impaired liver, kidney or respiratory function may be more susceptible to the effects of the substance.
- First aid measures for exposure to ethyl acetate:
  - In case of inhalation remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.
  - In case of ingestion give large amounts of water to drink. Never give anything by mouth to an unconscious person. Get medical attention.
  - In case of skin contact immediately flush skin with plenty of soap and water for at least 15 minutes. Remove contaminated clothing and shoes. Get medical attention. Wash clothing before reuse. Thoroughly clean shoes before reuse.
  - In case of eye contact immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.
- Potential health effects of ethanol:
  - Causes severe eye irritation. May cause painful sensitization to light. May cause chemical conjunctivitis and corneal damage.
  - Causes moderate skin irritation. May cause cyanosis of the extremities.
  - May cause gastrointestinal irritation with nausea, vomiting and diarrhea. May cause systemic toxicity with acidosis. May cause central nervous system depression, characterized by

excitement, followed by headache, dizziness, drowsiness, and nausea. Advanced stages may cause collapse, unconsciousness, coma and possible death due to respiratory failure.

- Inhalation of high concentrations may cause central nervous system effects characterized by nausea, headache, dizziness, unconsciousness and coma. Causes respiratory tract irritation. May cause narcotic effects in high concentration. Vapors may cause dizziness or suffocation.
- May cause reproductive and fetal effects. Laboratory experiments have resulted in mutagenic effects. Animal studies have reported the development of tumors. Prolonged exposure may cause liver, kidney, and heart damage.
- First aid measures for exposure to ethanol:
  - Eyes: Get medical aid. Gently lift eyelids and flush continuously with water.
  - Skin: Get medical aid. Wash clothing before reuse. Flush skin with plenty of soap and water.
  - Ingestion: Do not induce vomiting. If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid.
  - Inhalation: Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid. Do NOT use mouth-to-mouth resuscitation.
  - Notes to Physician: Treat symptomatically and supportively. Persons with skin or eye disorders or liver, kidney, chronic respiratory diseases, or central and peripheral nervous system diseases may be at increased risk from exposure to this substance.
  - Antidote: None reported.

### **Disposal:**

If it appropriate in your area, the volatile components of the mixture can be evaporated in a shallow pan under the vent hood. Be sure that no possible sources of ignition are in the area. When no odor of ethanol or ethyl acetate remains, the remainder of the mixture can be flushed down the drain. Please be sure that this method, or any other method of disposal that you use, complies with local, state, and national regulations for the disposal of hazardous wastes.