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Ed Vitz
Kutztown University
Kutztown, PA 19530

A Demonstration of Refractive Index Matching Using Isopropyl Alcohol and MgF_2

submitted by: **Frederick C. Sauls**
Department of Chemistry & Physics, King's College, Wilkes-Barre, PA 18711; *fcsauls@kings.edu*

checked by: **Michael R. Johnson**
Department of Chemistry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

The published demonstrations of the disappearance of a solid when placed in a liquid of matching refractive index used glass and mixtures of liquids such as benzene and chlorinated hydrocarbons or acetone *(1–3)*. The proportions of liquid must be fairly carefully controlled. The liquids are also are expensive (both to purchase and dispose) and toxic in both liquid and vapor form. Using them outside a hood is poor practice. More recently, it has been noted that borosilicate glass and vegetable oils have similar refractive indices *(4–6)*, as do water and polyacrylamide gels allowing their use. Although inexpensive and nontoxic, the oil tends to be messy and cleanup a chore. Its viscosity and immiscibility with water make it difficult to readily change its refractive index by mixing.

New Demonstration

Optical grade MgF_2 is available in small transparent chunks (few mm across).[1] Its refractive index of 1.378 almost matches 2-propanol (η = 1.3776). One may place a chunk of MgF_2 and a similarly-sized chunk of, for example, CaF_2 (η = 1.434)[2] or broken glass ($\eta \cong 1.52$) in a small beaker or Petri disk on an overhead projector. They can be clearly seen by an audience. When they are covered with 2-propanol the MgF_2 disappears, while the other is still fully visible but with reduced contrast. It may be necessary to swirl the 2-propanol and MgF_2 to displace air from the surface before the solid fully disappears. If deionized water (η = 1.3328) is then added from a wash bottle, the refractive index of the liquid is lowered and the MgF_2 reappears.

Three brands of isopropanol gasoline deicer were tested and worked well.[3] However, drug store isopropyl alcohol (rubbing alcohol) did not work well, as it contains a substantial proportion of water.

Isopropanol is readily biodegradable. The solids are of very low solubility in either isopropanol or water. Thus, when the demonstration is finished, the liquid may be disposed in the drain and the solids air dried for reuse.

Isopropyl alcohol is a common solvent in cosmetics, pharmaceuticals, inks, and finishes. CaF_2 and MgF_2 are transparent in the IR, visible, and UV. They are used in optical coatings, lenses, and windows. CaF_2 (fluorite) is the mineral source for HF and F_2.

Hazards

Hazards are minimal. Isopropanol is flammable, but its flash point of 11.7 °C and the small quantity required reduce this concern. It is also toxic by ingestion or inhalation of large quantities (although its common use as a body rub and in cosmetics suggest that this is not a major problem) *(7)*. CaF_2 has an $LD_{50} > 5$ g/kg (guinea pig) *(8)*, and MgF_2 an LD_{50} of 1 g/kg *(9)*. The latter is also a skin irritant. Neither should be brought in contact with strong acids or powerful oxidants, as HF(g) or F_2(g) may be liberated.

Notes

1. MgF_2 was purchased from Alfa Aesar, catalog #11021.
2. CaF_2 was purchased from Alfa Aesar, #11022.
3. Brands tested were: Berkebile 2+2 Isopropyl Gasline Anti-Freeze, Unifide Iso-Dri Fuel System Dryer, and Pitt Penn isopropyl gas line antifreeze. Note that some brands are methanol based and do not work in this application.

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