Colour is in the Direction of the Beholder

INTRODUCTION:
I stumbled on this fascinating effect when a student complained that her beaker full of white snow had turned purple when she added green antifreeze. The results were first published as "In Praise of Dirty Beakers." in the March 1998 issue of Chem13 News.

CHEMICAL CONCEPTS:
-fluorescence
-colour absorption
-colour change of an acid-base indicator dye

MATERIALS:
-fluorescein dye
-phenolphthalein dye solution
-dilute sodium hydroxide solution

PROCEDURE:

Use a flat toothpick to measure out a small amount of solid fluorescein dye. Add the amount that will rest on the flat end of the toothpick (about 0.1g) to a 2 L PET bottle and fill the bottle with distilled water. (The trick is to get a light "lime green". More dye is not necessarily better.) Add enough NaOH solution to the bottle to make it basic to phenolphthalein (about 2 mL of 0.1 M NaOH).

Select two 400-mL beakers that have clean sides and clean, even bottoms. Sprinkle a few drops of water in the bottom of each beaker. Add a few drops of phenolphthalein solution to one beaker. The water drops are distractors. It should look like you have just cleaned out the beakers without drying them.

Place both beakers on a lighted overhead projector and pour the green solution into the beaker with just water on the bottom. Talk about how the dye is absorbing the energy from white light and releasing it as green light that travels to the projection screen.

Now fill the beaker with phenolphthalein on the bottom. The liquid will appear green when viewed from the side, but it will produce a purple image on the screen.

Pretend not to notice….

NOTE: The effect is best seen when the beakers are at eye level. This is not the case for the demonstrator standing beside the overhead projector. You will see the one beaker as distinctly purple while your students will say that it is green. Since you have tried it ahead of time, this will not disturb your presentation!

SAFETY PRECAUTIONS:

Avoid contact with skin and eyes.

DISPOSAL:

The very dilute purple solution can be washed down the sink with lots of water. The solution without the phenolphthalein can be returned to your solution stock bottle.

DISCUSSION:

When fluorescein molecules are exposed to strong light, they absorb high-energy blue and ultraviolet light and re-emit that energy as a more intense yellow-green light of lower frequency. The effect is known as fluorescence.

When a solution contains phenolphthalein dye in its basic form, this dye absorbs yellow-green component of white light, allowing only red and blue light to pass through. The eye perceives the dye colour as purple.

When BOTH dyes are in solution, the path length to exit the solution becomes important. From the side, there are many fluorescein molecules close to the edge of the solution and the green light emitted in that direction escapes from the beaker. The light projected on the screen passes through the entire depth of the solution where it encounters many phenolphthalein molecules. Although molecules of fluorescein close to the top emit green light, the light reaching the screen is so deficient in the green component that the image appears purple.

ACKNOWLEDGMENT:

Christer Gruvberg of Halmsted, Sweden helped to convert the demonstration from using antifreeze to the present "Greener" version that involves no disposal issues.

An excellent reference on dyes and their interaction with light can be found at:

http://members.pgonline.com/~bryand/StainsFile/dyes/dyes.htm

Materials available from Flinn Scientific:
Catalog No. Description

F0043 Fluorescein dye
P0019 1% Phenolphthalein indicator solution