Required Training

UC Lab Safety Fundamentals

Performers Required: 1

Equipment

Five 100 mL beakers
Disposible pipettes

Chemicals

Phenolphthalein in ethanol solution
Sodium carbonate (Na$_2$CO$_3$), 5% solution
Iron (III) chloride (FeCl$_3$), 50% solution
Ammonium thiocyanate (NH$_4$SCN), 30% solution
Potassium ferrocyanide (K$_4$[Fe(CN)$_6$]), 5% solution

Procedure:

1. To prepare this demonstration, add the following to five separate beakers:
   1. 50 mL water and 1 drop phenolphthalein solution
   2. 1 drop of Na$_2$CO$_3$ solution
   3. 1 drop of FeCl$_3$ solution
   4. 1 drop of NH$_4$SCN solution
   5. 1 dro of K$_4$[Fe(CN)$_6$] solution
2. Pour the contents of beaker #1 into #2, then from #2 into #3, then from #3 into #4, and finally from #4 into #5. There will be a distinct color change with each successive step; #1 is colorless, #2 is fuchsia (basic phenolphthalein), #3 is yellow (acidic Fe$^{3+}$(aq)), #4 is red (Fe(SCN)$^{2+}$ species), and #5 is deep blue (Prussian blue).

Clean-up: The contents of beaker #5 can be diluted with water and rinsed down the drain.

Hazards: Ethanol solutions are flammable, and should be kept away from ignition sources. Solutions of FeCl$_3$ are corrosive to metals. Phenolphthalein, FeCl$_3$, and NH$_4$SCN are toxic if swallowed, and phenolphthalein is a potential carcinogen and reproductive hazard. The Prussian blue present in beaker #5 will stain skin and clothing.

Principle: This demonstration uses an indicator and several different reaction products to produce five different colors.
from a single solution. The indicator phenolphthalein is colorless in neutral solution (beaker #1), but turns fuchsia in the presence of the basic Na$_2$CO$_3$ solution in the second beaker. In the third beaker the H$_3$O$^+$ ions produced by the hydrolysis of the iron(III) salt bind the OH$^-$ ions from the Na$_2$CO$_3$ solution, leading to decolorization of the phenolphthalein; at the same time the solution turns yellow due to the presence of the hydrolyzed iron(III) species:

\[
[\text{Fe(H}_2\text{O)}_6]^{3+} + \text{H}_2\text{O} \rightarrow [\text{Fe(H}_2\text{O)}_5(\text{OH})]^{2+} + \text{H}_3\text{O}^+
\]

\[
[\text{Fe(H}_2\text{O)}_5(\text{OH})]^{2+} + \text{H}_2\text{O} \rightarrow [\text{Fe(H}_2\text{O)}_4(\text{OH})_2]^{+} + \text{H}_3\text{O}^+ \text{ etc}
\]

In the fourth beaker iron (III) salts form deep red complexes such as [Fe(SCN)(H$_2$O)$_5$]$^{2+}$ with the SCN$^-$ ions. The extreme stability of colloidal Prussian blue (KFe$^{III}$[Fe$^{II}$(CN)$_6$]) dominates in the fifth beaker, so that the deep blue color brings the series to a close. Deviations from the given concentrations can lead to slight differences in the effects due to the formation of precipitates or mixed colors.

**Notes:** Ensure the thiocyanate solution is fresh (< 3weeks old), as it slowly decomposes and gives muddy brown precipitates instead of the desired deep red color.