REACTIONS IN SOLUTION

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There are seven beakers, each containing a clear, colorless solution. When a solution is poured from one beaker to the next sequentially, a different phenomenon is observed.

TIME — Getting Ready: 45 - 60 minutes to prepare the solutions.
Doing the Demo: 10 minutes

MATERIAL
7 250 mL beakers or plastic cups
50 mL phenolphthalein solution
50 mL 0.20 M sodium carbonate solution (Na_2CO_3)
50 mL 0.20 M lead acetate solution
50 mL 0.80 M nitric acid solution
50 mL 0.40 M potassium iodide and 0.06 M ammonium thiocyanate soln
50 mL 0.02 M ferrous sulfate solution ($FeSO_4$)
50 mL 0.02 M potassium ferrocyanide solution

SAFETY — Nitric acid can irritate the skin and damage clothes. Its' vapor is extremely irritating to the eyes and respiratory system. Rubber or plastic gloves and an apron should be worn for these demonstrations. Lead acetate, potassium iodide, ammonium thiocyanate and potassium ferrocyanide can be toxic when inhaled or ingested.
Reaction solutions should be discarded in a receptacle for heavy metal wastes.

GETTING READY — To prepare the solutions:

1. Dissolve 0.05 grams of phenolphthalein in 50 mL of 95% ethanol, and dilute the resulting solution to 1 L with distilled water. Label #1.

2. Dissolved 21.2 grams sodium carbonate anhydrous, Na_2CO_3, in 200 mL distilled water and dilute the resulting solution to 1 L with distilled water. Label #2.

3. Dissolve 75.8 grams lead acetate trihydrate, $Pb(C_2H_3O_2)_2\ 3H_2O$ in 300 mL distilled water and dilute the resulting solution to 1 L with distilled water. Label #3.

4. Pour 100 mL of concentrated nitric acid, HNO_3 into 500 mL distilled water and dilute the resulting solution to 1 L with distilled water. Label #4.

5. Dissolve 66.4 grams potassium iodide, KI, and 5.28 grams ammonium thiocyanate, NH_4SCN, in 250 ML distilled water and dilute the resulting solution to 1 L with distilled water. Label #5.

6. Dissolve 5.56 grams ferrous sulfate heptahydrate, $FeSO_4\ 7\ H_2O$ in 100 mL distilled water and dilute the resulting solution to 1 L with distilled water. If the solution is slightly brown, put a small amount of iron powder into the solution and add 5-10 mL concentrated sulfuric acid. Let stand for a day. Label #6.

7. Dissolve 8.44 grams potassium ferrocyanide hexahydrate $KFe(CN)_6\ 6H_2O$ in 100 mL distilled water and dilute the resulting solution to 1 L with distilled water. Label #7.

8. Label seven 250 mL beakers or plastic cups #1 through #7. Pour about 50 mL of the appropriate solution into each beaker. The solutions in the beakers should look colorless and clear. Arrange the beakers in order.

DOING ACTIVITY

Pour the solution for #1 beaker into #2 beaker, you will observe the solution turns pink and looks like fruit juice or kool-aid.

Pour all the solution from #2 beaker into #3, stirring it. Observe the solution becomes opaque and white and looks like milk.

Pour the mixture from #3 into beaker #4, and stir. The solution turns clear and colorless and gas is released. It looks like soda water.

Pour the clear solution from #4 into beaker #5, the solution turns yellow and opaque and looks like paint.

After some of the yellow precipitate has settled, pour the clear liquid from #5 into beaker #6. The solution turns red and looks like blood or tomato juice.

Pour the solution from #6 into #7, the solution turns into a deep blue and looks like ink.

EXPLANATION

The reactions are mostly ionic reactions. They include acid-base reactions, precipitation reactions, complex ion reactions and oxidation-reduction reactions.

Rx. 1 The sodium carbonate is a salt in which the Na^{+1} cations do not react with water, and the CO_3^{-2} anion is a stronger base than water so its' solution is alkaline. When phenolphthalein is added to this alkaline solution it will turn red.

Rx 2. When this solution containing CO_3^{-2} anions is poured into beaker #3 which contains lead ions (Pb^{+2}), a white precipitate, $PbCO_3$, is formed.

Rx 3 When this mixture which contains lead carbonate is poured into beaker #4 containing nitric acid, the precipitate dissolves and releases carbon dioxide gas and the solution becomes clear and colorless again.

$$PbCO_3 + 2\,H^{+} \rightarrow Pb^{+2} + H_2O + CO_2$$

Rx 4 When the solution containing the lead ions is pourted into beaker #5 which contains iodide ions, I^{-1}, the yellow precipitate lead iodide is formed.

$$Pb^{+2} + 2\,I^{-1} \rightarrow PbI_2\,(s)$$

Rx 5 When the solution containing excess nitric acid and thiocyanate ions is poured into beaker #6 which contains ferrous ions (Fe^{+2}), the ferrous ions are oxidized by the acid to form ferric ions (Fe^{+3}).

$$3Fe^{+2} + NO_3^{-1} + 4\,H^{+1} \rightarrow 3\,Fe^{+3} + 2\,H_2O + NO$$

The ferric ions will form the bright red ferric thiocyanate complex ion:

$$Fe^{+3} + 3\,SCN^{-} \rightarrow Fe(SCN)_3$$

If there is yellow precipitate suspended in the red solution, the mixture will be orange

Rx 6. When the mixture containing ferric ions is poured into beaker #7 containing the ferrocyanic ions $[Fe(CN)_6]^{-4}$, the deep blue potassium ferric ferrocyanide will be formed which is known as Prussioan blue:

$$K^{+1} + Fe^{+3} + Fe(Fe(CN)_6^{-4} \rightarrow KFe[Fe(CN_6]$$

REFERENCES

Therald Moeller, John. C. Bailar, Chemistry; Academic Press, 1984.

Bassam Z. Shakhashiri: Chemical Demonstrations, Vol. 3, Wisconsin University Press, 1989.