Metal Ligand

Contributed by the Chemistry Student Association at The University of Texas at Dallas

Main Science Idea for Kids

This activity is integrated into a crime scene investigation, in which dirt is found under each suspect's shoe. Each dirt sample is then compared to dirt found at the crime scene. Since all the samples look identical, Windex is sprayed onto each sample to produce a color that depends on the metal residing in the dirt. The color of each sample is then compared to that of the dirt found at the crime scene. By matching identical colors across different samples, we might be able to determine the real culprit.

Students will learn that transition metals tend to change color when they bond with ammonia. These complex ions absorb light differently which causes the color to change. The color changes are so reliable and distinct that testing samples of dirt containing transition metals with ammonia can be used to help identify an unknown.

Grade Level

We have done this activity with high school students. However, if the explanation were simplified, we could see this activity being suitable for middle school or upper elementary students too.

How We Introduce this Activity

We explain what happened at the crime scene and say that dirt was found at the crime scene as well as under each suspect's shoe. Then, we explain how to use the properties of complex ions between metal and ligand to detect the difference in these dirt samples, since they all look identical. We then go over the procedure, which involves spraying Windex onto each sample. Since Windex contains ammonia, the ammonia binds to the metal ion in each sample, producing a highly visible color unique to the metal ion. Finally, we say how that will help in determining who the real culprit is by matching the samples' colors to that of the dirt found at the crime scene.

Materials

- 5 glass or plastic vials that contain approximately 5 ml each
- Salts containing Cu^{+2}, Mn^{+2}, Zn^{+2} or any other transition metal
    - copper sulfate, $CuSO_4$
    - manganese sulfate, $MnSO_4$
    - zinc sulfate, $ZnSO_4$
    - potassium chloride, KCl
- Sand (bought from a hardware store)
- Windex, generic ammonia-containing glass cleaner, or ammonia
  (We like to use Mountain Berry Windex which is light pink. The color changes are not as dramatic if you use blue window cleaner.)

Materials Preparation

1. Pour a little (0.25-0.5 g) of each salt into each of 4 vials using a metal spatula. In the 5th vial, add $CuSO_4$. In the end, you should have $CuSO_4$ in 2 vials rather than 1.
2. Label each vial from 1-4 (one for each suspect). The 2nd vial with CuSO4 should be labeled as the sample found at the crime scene.
3. Pour some sand into each vial and then stir so that the salt is barely visible. All the vials should look identical.

Procedure

1. Hold the bottle of glass cleaner so that the nozzle is directly over the opening of the vial of sand collected from Suspect 1. (If using ammonia, use a dropper to add the ammonia to the vial.) Then spray glass cleaner or add drops of ammonia until there is a small layer of liquid over the sand and an observable color change. **Note:** The KCl vial displays no color just to show that most complexes of the representative metals are colorless.
2. Spray glass cleaner or add ammonia to the vials for Suspects 2, 3, and 4 and observe the color changes.
3. Hold up the last vial and explain that this sample was found at the crime scene. Spray glass cleaner or add ammonia until there is a noticeable color change.
4. Compare the color change from this last vial “collected at the crime scene” to the color changes of the vials of sand “collected from each suspect.”

Which suspect does this evidence point to?

The Chemistry Explanation

The activity demonstrates complex ion formation between a ligand and transition metal. Complex ions are formed when the ligand donates an unshared electron pair to the metal ion, forming a metal-ligand bond called a *coordinate covalent bond*. The ligand, in this case, is the ammonia found in Windex. The color change is most often seen with transition metals because the complex ion absorbs light at a certain energy that corresponds to that of a visible color. The color that we see is the complementary color. For example, if a complex ion absorbs blue light, what we see is a yellow color.

We Like this Activity

The activity is simple, easy to perform, and demonstrates a very interesting concept that is rarely taught to high school students. Most importantly, students enjoy the activity's qualitative aspect because they can observe visible colors that are pleasing to the eyes.

About Us

The Chemistry Student Association at UT Dallas is a student organization that strives to foster interest in the sciences among students of all ages through interactive chemistry and informative sessions, to serve as a liaison between students and the chemistry faculty, and to provide support and a social community for students with a common interest in chemistry. Some of our favorite service events include Texas Instruments' Family Day, which involves slime, chemistry demos, and a crime scene investigation using chemistry, and "Kids in Chemistry," which involves slime, chromatography, acid/base, and pizza. Our traditional social events include barbecues with dessert competitions and the end-of-semester broomball game between professors/graduate students and undergraduates.

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