**Turmeric Can be Used as a Colored Indicator of the pH of Common Household Solutions**

Organic chemistry reactions do not have to happen in a laboratory with expensive equipment to be interesting and complex. The experiment “Changing Turmeric from Yellow to Red” uses easily found household items to see the principles of chemistry in action. The method used for this experiment was based off the procedure in:


**The first version of a video of this procedure was produced in 2015 by** Tanya Thomas, Miranda Allen, Gilbert Brooks, III, Bashir Aedeed. This video vanished into history, and the current version of the video was produced in 2018 by Alexander Wilson and Darius Jonasch. In 2018, the procedure was as below.


**Procedure**

1. Approximately 2 teaspoons of turmeric powder were added to water, approximately 0.25 cups). The mixture was stirred to partially dissolve curcumin. The suspension was yellow in color.

4. A series of solutions were prepared by adding to water one of the following:
   (a) A teaspoon of baking soda (sodium bicarbonate, NaHCO₃). Assume a solution pH~9.
   (b) Vinegar, which contains acetic acid (CH₃CO₂H). Assume this solution has a pH~2.
   (c) Concentrated household bleach, which contains NaOCl. Assume a solution pH~13.
   (d) Water. Assume this solution has a pH~7.
   (e) Sodium hydroxide. Assume this has the highest pH of the solutions.

5. Each solution was added to the turmeric-containing mixtures. Color changes were observed.

**Observations**

1. When the baking soda solution was applied to the yellow paper, the mixture turned a burnished red.
2. When the bleach solution was applied, the mixture turned red.
3. When either the vinegar or the water solution was applied to the yellow mixture, the mixture remained yellow.
4. When the mixture was treated with sodium hydroxide, the mixture turned red.
Background

Tumeric powder is an inexpensive yellow-orange spice that is used to give some brands of mustard a bright yellow color. This color derives principally from curcumin (1, 2). The procedures in this video involve the below proton transfer equilibria.

Recall: When light is absorbed, your eye detects the complementary color.

<table>
<thead>
<tr>
<th>Wavelength of light</th>
<th>Complementary Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violet: 400 - 420 nm</td>
<td>Yellow</td>
</tr>
<tr>
<td>Indigo: 420 - 440 nm</td>
<td>Yellow</td>
</tr>
<tr>
<td>Blue: 440 - 490 nm</td>
<td>Orange</td>
</tr>
<tr>
<td>Green: 490 - 570 nm</td>
<td>Red</td>
</tr>
<tr>
<td>Yellow: 570 - 585 nm</td>
<td>Indigo &amp; Violet</td>
</tr>
<tr>
<td>Orange: 585 - 620 nm</td>
<td>Blue</td>
</tr>
<tr>
<td>Red: 620 - 780 nm</td>
<td>Green</td>
</tr>
</tbody>
</table>

Questions

A. Review

1. Apply what you know about conjugated π-bonding systems to explain why the maximum absorbance wavelength for the keto-enol tautomer 1 should be longer than that for diketone 2.

2. There has been some debate in the scientific literature about whether the keto-enol tautomer 1 or diketone 2 predominates at neutral pH~7. If the calculations for the maximum absorbance wavelength are correct, which of these compounds do you see on the initial yellow paper? Why might that compound be more stable?

3. If the calculations and experimental values for the maximum absorbance wavelength are correct, which compounds could be responsible for the red color in the paper?

B. Explain your observations: Use mechanistic arrows to explain why the color of curcumin and its derivatives depend on pH.

4. In principal, water can affect the interconversion of keto-enol tautomer 1 and diketone 2. Draw arrow-pushing mechanisms using water to interconvert 1 and 2.

5. Draw an arrow-pushing mechanism to explain why the baking soda solution transformed the yellow paper to red paper. What is the role of baking soda in this reaction?

6. Though not shown in this video, draw an arrow-pushing mechanism to explain why the vinegar solution transforms mixture into a yellow mixture. What is the role of vinegar in this reaction?

7. Why doesn’t the vinegar solution cause the yellow mixture to change colors?

C. Once you have completed this worksheet, and reviewed the answers, respond to the following questions.

8. Write 1-2 sentences to explain what you have learned from this worksheet.

9. Was this exercise useful? Why or why not? Provide 1-2 suggestions to improve the worksheet.

D. If you have completed this worksheet, turn in your answers to Prof. Roizen.

The initial draft of this worksheet was prepared by Tanya Thomas, Miranda Allen, Gilbert Brooks, III, Bashir Adeed (2015) to accompany their procedural video. It has been adjusted by Prof. Jennifer Roizen (2016 and again in 2020).