5.7 Breathalyzer – Oxidation of ethanol by chromate

Subject: Kinetics, oxidation/reduction

Description: Primary and secondary alcohols are oxidized by $K_2Cr_2O_7$ to carboxylic acids and ketones respectively. The oxidation is physically observed by the change in color upon reduction of Cr^{6+} (orange) to Cr^{3+} (blue). This demonstration also illustrates the chemistry behind an earlier version of a test for blood alcohol content.

Materials:
10 mL 0.015 M $K_2Cr_2O_7$ (in 3 M H_2SO_4) ‡
Large test tube
10 mL Ethanol ‡
2 10 mL graduated cylinder
Glass stirring rod

‡The acidic chromate solution is located in the storage cabinet under the hood. The ethanol is located in the flammables cabinet.

Procedure:
Note: It may be necessary to project this demonstration using a document camera.
1. Add the ethanol to a test tube.
2. To this, add the acidic 0.015 M $K_2Cr_2O_7$ solution.
3. Mix with the glass stirring rods and over time the solution will change from yellow to green and finally to blue.

Kinetics options: use different concentrations of alcohol to see the effect on the rate of color change. Use a secondary alcohol to see effect on reaction rate. Perform in hot water or a cold bath to see effect on rate.

Discussion:
The dichromate anion ($Cr_2O_7^{2-}$; Cr^{6+}) is commonly used to oxidize alcohols. Upon reaction with a primary or secondary alcohol (tertiary alcohols will not be oxidized), the chromium (VI) in dichromate (orange) is reduced to Cr (III) and this species is observed in solution with the appearance of a blue color. This color change is the chemical basis for the breathalyzer as ethanol (1˚ alcohol) is readily oxidized by $Cr_2O_7^{2-}$ resulting in an observed change to the visible spectrum of the solution.

The general reaction for this demonstration is shown below:

$$3\ RCH_2OH + Cr_2O_7^{2-} + 8\ H^{1+} \rightarrow 3\ RCHO + 2\ Cr^{3+} + 7\ H_2O$$

Safety: Wear proper protective equipment including gloves and safety glasses when preparing and performing this demonstration. $K_2Cr_2O_7$ is toxic and a

carcinogen and exposure should be avoided. H_2SO_4 can cause burns and should be handled with caution.

Disposal: Solutions should be neutralized with $NaHCO_3$ and disposed of in an appropriate waste container.

References:

1. Procedure from: NCSU Department of Chemistry Lecture Demonstration Website: http://www.ncsu.edu/project/chemistrydemos/DemoList.html
2. Burke, B. A. J. *College Science Teaching* 1991, 21, 176.
3. Anderson, J. M. *J. Chem. Educ*. 1990, 67, 263.
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4. Labianca, D. A. *J. Chem. Educ*. 1990, 67, 259.
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