Alcohol and its Systematic Oxidation

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Ethyl alcohol is very interesting. It is perhaps the most commonly abused substance — so much so that law enforcement frequently stops drivers to perform sobriety tests. To gain an objective handle on this judgment, the breathalyzer, developed decades ago, used the reaction:

$$2Cr_2O_7^{2-} + 3C_2H_5OH + 16H^+ \leftrightarrows 4Cr^{3+} + 11H_2O + 3HC_2H_3O_2$$

Since the dichromate ion has an orange cast while the chromate ion has a green tinge, changes in absorbance can be used as a determinate of alcohol. So information flows from blood, to breath, to chromate ion, and than back by calculation to % alcohol in blood!

Of course, more pedestrian uses of the above reaction allow for the precise determination of alcohol in beer, wine and other spirits. Due to the complex nature of these beverages steam distillation, or some other method, must first be used to separate the alcohol from its matrix. In the past, when UTC students use this method for determining alcohol in beer, it was necessary to titrate excess dichromate ion with iron (II) to indirectly determine the alcohol. Now, having developed an automated spectrophotometric titration system capable of collecting spectra throughout the uv-visible region every second, it would be interesting to see if this process can be shortcut by direct titration of the alcohol with dichromate.

Beyond the limited goal of improvements in precise alcohol determination there is the much richer possibility of learning details of how exactly dichromate oxidizes ethanol to acetic acid. Like most chemistry, the reaction, as written above, looks simple until one really thinks about it, plays with the numbers and tallies the odds — it is not very likely that a 2:3 (dichromate to alcohol) reaction occurs in a one step process. Further reducing the probability of direct reaction are the mechanics of shuttling 6 electrons from each dichromate to feed 4 electrons to each alcohol. It seems quite reasonable to conclude that a multistep process must account for the pathway between reactants and products. To test this conclusion details of the journey from reactants to products must be examined, which is not the easiest of tasks.

Fortunately, our automated system produces time-lapsed reaction spectra. Analog thinking presents this information as 3-D graphs to be examine for revelations; a very human approach. Digital preservation allows matrix algebra to digest the wavelength-abosrbance-time data to extract information. Our ReactLab™ software provides most of the data analysis needed for this task.

It will be the responsibility of the student recruited to this project to take shared ownership of it. It is expected that this work will produce reaction details worthy of presentation at a professional meeting, perhaps the 2013 Southeast Regional Meeting of the American Chemical Society in Atlanta Georgia.

"Determination of alcohol in breath for law enforcement," Richard S.Theptow, J. Chem. Ed. 51, 641, (19744).