Utility and Implications of Controlled Potential Electrochemical Electrospray (CPEES) Mass Spectrometry

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A controlled potential electrochemical electrospray (CPEES) emitter cell was used to control the identity of, and extent to which individual analytes were electrolyzed in the electrospray source. This technology provided a means to initiate and folllow electrochemical reactions, reduce the number of analyte ionic species – oftentimes to a single ion, oxidize analytes in negative ion mode, reduce ions in positive ion mode and monitor short lived intermediates that were formed in the source.

The electrochemical reactions that are associated with the electrospray process have, historically, not been controlled. A conductive emitter in contact with solution and subjected to the high voltage (HV) electric field of the the electrospray (ES) ion source will adopt an interfacial potential, $\Delta\phi$, that results in the formation of ions required to promote and sustain the ES process. Uncontrolled, $\Delta\phi$, is influenced by the required ES current (i_{es}), solution composition, temperature, electrode area (i.e., the exposed conductive emitter surface) and flow rate. The inherent electrochemistry (EC) of the ES emitter is indiscriminant, electrolyzing any solution component that can undergo electron transfer – be that the solvent system or the analyte – to maintain i_{es}. In this presentation we address the use of a porous CPEES cell to selectively oxidize/reduce *p*-chloroaniline, reserpine and 2,5-diydroxybenzoic acid (DHB), follow electrochemical reactions, monitor short-lived intermediates formed in the emitter, and reduce the number of analyte ionic species. Furthermore, we demonstrate that the CPEES cell adds the possibility of reducing analytes in the positive ion mode and oxidizing analytes in the negative ion mode.

The observed analyte ionic species of *p*-chloroaniline were controlled by oxidizing the monomer to the oxidized dimer in an upstream EC cell and subsequently reducing the oxidized dimer to the reduced dimer (Figure 1, Scheme I). These results indicate that controlled reduction in the ion source while operating in the positive ion mode is possible.

Similarly, the poorly understood, stepwise oxidation of the commonly used ES-MS calibrant reserpine, was followed with the use of an upstream EC cell and a porous CPEES cell (data not shown). Careful control of the respective cell potentials made it possible to sequentially monitor each of the four possible analyte ionic species and propose a reaction pathway for the analyte.

The oxidation of 2,5-dihydroxybenzoic acid (DHB) was performed in negative ion mode (Figure 2, Scheme II) yielding the quinone and an intermediate believed to be a radical.

This work presents a novel means to gain an additional degree of flexibility over the electrospray ion source. The controlled electrochemistry that is achievable in the ES emitter using a porous CPEES cell can: Reduce the number of analyte ionic species formed; allow the study of short-lived species formed in the emitter; enable one to follow redox reactions; and perform analyte electrolysis with the opposite polarity of the ion source.

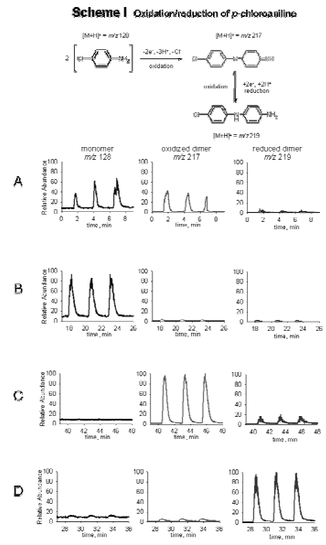

Figure 1 Comparison between four modes of oxidation/reduction of *p*-chloroaniline using an upstream EC cell and the CPEES emitter. Three 20 µL aliquots of 100 µM *p*-chloroaniline were injected at a flow rate of 50 µL/min at each configuration. (A) the extracted ion chromatograms for the three analyte ions when the upstream EC cell and CPEES cell are turned off, i.e., inherent emitter electrolysis, (B) EC cell off, CPEES cell set to -1 V, (C) EC set to +1 V, CPEES off and (D) EC cell set to +1 V, CPEES set to -1V.

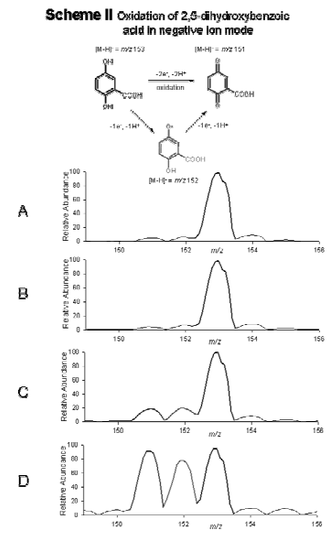

Figure 2 Full scan (*m/z* 149 – 156) data depicting the controlled oxidation of DHB in negative ion mode. Only the CPEES cell was used to acquire these data. (A) the inherent oxidation of DHB, i.e., CPEES cell off, (B) CPEES cell set to -1 V, (C) CPEES cell set to 0V for partial oxidation of DHB and (D) CPEES cell set to +1V for further oxidation of DHB to the quinone through what is presumed to be a radical intermediate.

[**1**] Van Berkel, G.J., In Electrospray Ionization Mass Spectrometry; Cole, R.B., Ed.; Wiley: New York, 1997; Chapter 2, pp 65-105.

[**2**] Van Berkel, G.J.; Asano, K.G.; Granger, M.C., *Anal. Chem.* **2004**, *76*, 1493-1499.