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EDITORIAL

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A state of excitement

The present author was recently privileged to see the first chapter of a new book on Electrochemistry. It was called: "A State of Excitement". This resonated so much with his view that he decided to make it the title of this foreword.

1. To start with the most exciting development: the certainty of an electrochemical (fuel cell driven) transportation system! The argument (cf. the announcement by Mercedes of 100 000 electric cars in 2002) is unambiguous. To reduce greenhouse gases, and to obey the environmental laws of most countries, it will be necessary, by 2002, to produce a significant number of electric cars. This had been thought to mean battery-powered cars, but the argument for fuel cells *with on-board reforming of a fossil fuel to produce hydrogen* is politically and scientifically convincing. Thus, batteries need electricity, and this would be made by burning coal to CO_2 and SO_2. Conversion of, e.g., methanol to hydrogen and electricity produced in a fuel cell will give rise to half the CO_2 formerly produced and no other polluting gases. The range could be double that of present cars.

2. Can we *fix* CO_2? Some recent Swiss work shows reasonable economics for electrochemical extraction of CO_2 from the atmosphere with hydrogen as a byproduct. A recent advance in catalysis makes possible the production of methanol from CO_2 and hydrogen. What of the future possibilities of producing, in this way, sufficient methanol for the transportation section of our economy?

3. The reduction of greenhouse gases may be the first environmental imperative, but the second is surely a non-pollutive way to deal with wastes, toxic products from which are beginning to reach the water table. Two electrochemical methods for waste remediation evolved during the 1990s. In the first, the oxidation to CO_2 takes place at ca. 120 °C by means of mediator ions, e.g., of Ag or Fe, which oxidize organic wastes to CO_2, the metal ions being continuously re-oxidized at the anode. The method is of universal application, and has been shown in US and UK industrial laboratories to remediate a large number of organics from sewage to old boots. A direct method of oxidation of sewage on SnO_2 (Sb-doped) anodes has also been proven. This second method has the possibility of being made electro-generative.

3. Biomedical. Here there is a surfeit of rich development. (1) Cholesterol concentration in the blood may indeed be important, but coagulation of platelets on the arterial wall depends on its surface charge. (2) A *general* cause of disease-free radical formation begins with the action of superoxide, O_2^-, an intermediate in the electrochemical reduction of O_2 on enzymes. (3) One of the possibilities of internal prosthetics has an implant consisting of a fuel cell running on blood glucose and arterial oxygen, operating at 12 W and powering an artificial heart. All these are as yet in the research stage – with several more bioelectrochemical themes.

5. Nano-structures. It has been found possible to use the tips of scanning tunneling microscopes to cause metal deposition of as few as five or six atoms per cluster. The method has unique possibilities, both in the formation of regulated nano-structures and in increasing the efficiency of catalysis (all atoms per cluster active!).

6. Single-electron tunneling. We always *imagine* electric currents as electron flow. However, if the interface is sufficiently small and the temperature sufficiently low, it is now possible to detect and measure single-electron transfers. They do not occur when the electron transfer at an interface is in rate control but when the process is under diffusion control. This is because, then, electron transfer is fast enough to leave the local electrode charge density unaffected for the electron tunneling time.

Do these areas show something bigger, suggesting a rather general, but quite new, conclusion? Our educational system, and the textbooks of physical chemistry, show the accepted paradigm potraying *chemical* (i.e., thermally activated) reactions as *general* and *electrochemical* ones as a *special* sub-case. But let us count up the most common reactions in nature. Photosynthesis must lead, for it introduces the energy of solar photons into the food chain. Metabolism and energy production at 50% efficiency is another; corrosion of materials is a third. All have electrochemical steps, in the first and third examples accepted as photoelectrochemical and electrochemical, respectively, and as for the second, – well – how can one explain a 50% efficiency of energy conversion outside a fuel cell type mechanism?

Thus, electrochemical mechanisms dominate in nature. With this background added to the need to introduce technology to reduce global warming, it is not too much to suggest that we live in the early stages of an electrochemical revolution in technology, and indeed in how we live. Our technological civilization started with Newcomen's steam engine pumping water from mines (1728). For 270 years we burned our fossil cache and have come to within a generation of exhausting the liquid part of it. It is not only CO_2, which makes a continuance of this mode of energizing our civilization unacceptable, but questions are now rationally asked concerning interference with the air oxygen concentration. Fusion of atoms (whether on earth or in the sun) must be our future source of energy, and that energy will be stored and transmitted in hydrogen, then used in the form of electricity. In this way, a steady-state clean world is possible. The problem is: how long have we got to bring it out? In the provision of a clean and steady-state world, electrochemists will have very much to do.

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