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Energy conversion and fuel production from electrochemical interfaces¹

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Design and synthesis of energy efficient and stable electrochemical interfaces (materials and double layer components) with tailor properties for accelerating and directing chemical transformations is the key to developing new alternative energy systems – fuel cells, electrolizers and batteries. In aqueous electrolytes, depending on the nature of the reacting species, the supporting electrolyte, and the metal electrodes, two types of interactions have traditionally been considered: (i) direct – covalent bond formation between adsorbates and electrodes, involving chemisorption, electron transfer, and release of the ion hydration shell; and (ii) relatively weak non-covalent metal-ion forces that may affect the concentration of ions in the vicinity of the electrode but do not involve direct metal-adsorbate bonding. The range of physical phenomena associated with these two classes of bonds is unusually broad, and are of paramount importance to understand activity of both metal-electrolyte two phase interfaces and metal-Nafion-electrolyte three phase interfaces. Furthermore, in the past, researcher working in the field of fuel cells (converting hydrogen and oxygen into water) and electrolyzers (splitting water back to H₂ and O₂)) seldom focused on understanding the electrochemical compliments of these reactions in battery systems, e.g., the lithium-air system. In this lecture, we address the importance of both covalent and non-covalent interactions in controlling catalytic activity at the two-phase and three-phase interfaces. Although the field is still in its infancy, a great deal has already been learned and trends are beginning to emerge that give new insight into the relationship between the nature of bonding interactions and catalytic activity/stability of electrochemical interfaces. In addition, to bridge the gap between the “water battery” (fuel cell ↔ electrolyzer) and the Li-air battery systems we demonstrate that this would require fundamentally new knowledge in several critical areas. We conclude that understanding the complexity (simplicity) of electrochemical interfaces would open new avenues for design and deployment of alternative energy systems.

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