Heat Engines Based on Redox Work

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The science and engineering of heat engines have largely focused on energy conversion between heat and mechanical or electrical work. We present two types of heat engines for work based on redox reactions.

We first present a continuous electrochemical heat engine (CEHE) that leverages the advances in flow batteries for direct heat to electrochemical work [1]. Using stacks of electrochemical cells driving flowing electrolytes in symmetric redox reactions at different temperatures, we demonstrate two continuous electrochemical heat engines that operate at 10–50ºC and at 500–900 ºC, respectively. Simulations suggest system efficiencies over 30% of the Carnot limit and areal power densities competitive with solid-state thermoelectrics at maximum power. The key advantage is the ability to fully decouple entropy conversion, thermal transport, and electrical transport.

Hydrogen produced by splitting water is one of the most fundamental reactions in energy research. We report the development of a new class of materials – entropy stabilized oxides (ESOs) [2] – that harnesses the large entropy change during a solid-solid phase transition to thermochemically split water and produce H_2 at temperatures down to 1100 ^oC. This is a significant breakthrough over previously reported ones at 1500 ^oC, because it enables compatibility with the infrastructure of the existing chemical industry. Despite the preliminary success, there are numerous unanswered questions with regards to the thermodynamics, kinetics and chemistry of these redox reactions using ESOs. Deeper understanding will not only allow the possibility of temperature reduction <1000 ^oC but also sufficiently high kinetics to make this approach industrially relevant. This approach has the potential to open new options for low-cost low-carbon H_2 production as well as other important redox reactions, such as reduction of CO_2.

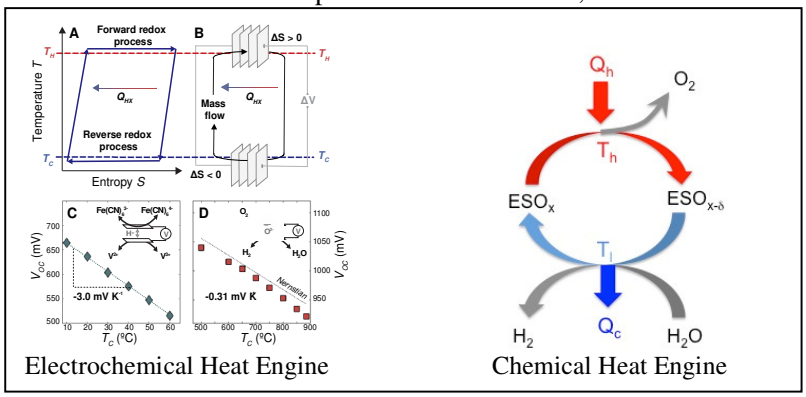

Fig. 1: Electrochemical and chemical heat engines to convert heat into redox work.

[1] A.D. Poletayev, I.S. McKay, W. C. Chueh, A. Majumdar, "Continuous electrochemical heat engines," (under journal review)

[2] C. M. Rost, E. Sachet, T. Borman, A. Moballegh, E. C. Dickey, D. Hou, J. L. Jones, S. Curtarolo, J.-P. Maria, Entropy-stabilized oxides. *Nat. Commun.* **6**, 8485 (2015).