Chemical plant analysis of hydrogen production from the hybrid sulfur-ammonia water splitting cycle

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Abstract

Solar-powered thermochemical water splitting cycles (TWSC) can potentially reach overall efficiencies of 35-40\%, far exceeding that of other solar-to-H\textsubscript{2} conversion systems (e.g., PV-electrolysis, photo-electrochemical, photocatalytic, photo-biological). However, existing solar TWSC face number of challenges that have slowed their practical application: (i) the utilization of only the thermal (IR) component of the solar irradiation, neglecting a photonic (UV-Vis) component, (ii) the intermittent nature of the solar resource, and (iii) the reliance on technically-challenging reagents transport and separation stages. This work presents the process simulation and preliminary sensitivity analysis of the hybrid photo-thermal sulfur-ammonia water splitting cycle; a novel photo-thermochemical process that takes advantage of a wider spectrum of the solar radiation. The developed process consists of mainly five unit operations (a photochemical, three thermochemical & an absorber). It incorporates also two thermal energy storage systems based on process fluids (molten salts and gases) rather than external heat transfer fluids. An optimum solar-to-H\textsubscript{2} efficiency of 25.5 \% was predicted, on the basis of 7,000 kmol.h\textsuperscript{-1} produced H\textsubscript{2}, higher than previous attempts. At the same time, to achieve this higher efficiency, higher reactor temperatures than those predicted by previous thermodynamic calculations are needed. Finally, the preliminary sensitivity analysis shows that mainly the mid-temperature thermochemical reactor and the composition of the feed affect the overall performance of the cycle.