# Hydrogen Production Using Nuclear Reactors Offers Energy, Environmental Benefits

Argonne is investigating two ways to use water to make hydrogen for the "hydrogen economy" using a nuclear reactor as a source of heat and electricity. There are advantages to both processes—high-temperature (steam) electrolysis, and a hybrid thermochemical-electrochemical cycle—but there also are materials-related challenges, which Argonne is working to meet.

## High-Temperature (Steam) Electrolysis

High-temperature electrolysis (HTE), or steam electrolysis as it is also called, uses electricity to produce hydrogen from steam, instead of liquid water. High-temperature electrolysis is more efficient than traditional room-temperature electrolysis because some of the energy is supplied as heat, which is cheaper than electricity, and because the electrolysis reaction is more efficient at higher temperatures.

Argonne is part of a team demonstrating the feasibility of this process using Argonne's background in solid oxide fuel cell designs and materials. The major source of inefficiency in both solid oxide fuel cells and solid oxide electrolysis cells is poor electrode performance and durability, which results in large systems and high materials costs. Argonne is developing oxygen and hydrogen electrode materials for better hydrogen production efficiency and materials durability, respectively.

## Hybrid thermochemical-electrochemical cycle

Recent research indicates strong potential for using thermochemical water splitting processes to produce hydrogen. Thermochemical cycles are a series of chemical reactions that convert water to hydrogen and oxygen using chemical catalysts at high temperatures. These processes offer the potential for high-efficiency hydrogen production at large-scale production rates, but the technology is relatively immature.

Researchers Jennifer Mawdsley (Chemical Engineering Division, right), and Bilge Yildiz (Nuclear Engineering Division, left) prepare to conduct electrochemical tests of a high-temperature steam electrolysis electrode material.

Argonne is investigating a thermochemical hybrid hydrogen production cycle that produces hydrogen from water, also using heat from a nuclear reactor. The proposed cycle is based on the sulfuric acid ($H_2SO_4$) synthesis and decomposition processes developed earlier, termed the sulfur-iodine cycle. The standard sulfur-iodine cycle requires temperatures above 800°C for one step in the cycle, the decomposition of sulfur trioxide ($SO_3$). The other reactions in the cycle can be performed below 500°C.

Argonne's work is focusing on a means to lower the temperature of the $SO_3$ to $SO_2$ reaction to 500-600°C. The benefits of lowering the maximum operating temperature of the cycle are that it allows the use of a lower temperature heat source, eliminates the need for expensive high-temperature heat exchangers, and it mitigates the problems associated with corrosion at higher temperatures. One potential way to lower the working to develop improved materials and cell designs to maximize the efficiency of this step in the hydrogen production cycle for operation at ~500°C. maximum temperature is to electrolyze $SO_3$ using oxide-ion-conducting electrolysis cells. Argonne is This work is funded by U.S. Department of Energy, Office of Nuclear Energy, as part of the Nuclear Hydrogen Initiative.

## For More Information

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For more information on Argonne's R&D under the Nuclear Hydrogen Initiative, visit www.cmt.anl.gov/Nuclear_Hydrogen_Production.shtml

**Making hydrogen today**

Currently, the only economical, large-scale method of hydrogen production involves the conversion of methane into hydrogen through a steam reforming process. Steam reformation produces most (about 95%) of the hydrogen produced in the United States. The process is efficient but has the environmental drawback of producing large quantities of carbon dioxide as a by-product.

The other commercially used method, electrolysis, converts water into hydrogen using electricity. Electrolysis is typically used for small production quantities and will probably be uneconomical for large-scale production, because electricity must first be produced to run the equipment used to convert the water into hydrogen. **The maximum environmental benefits of electrolysis to produce hydrogen are realized when a non-emitting technology, such as nuclear energy, is used to produce the electricity.**

Promising new hydrogen production technologies take advantage of the high temperatures generated in some of the advanced high-temperature nuclear reactors. These advanced reactors will be able to provide the low-cost heat necessary for these processes to economically produce hydrogen; they are being developed by the Generation IV (Gen IV) Nuclear Energy Systems Initiative.