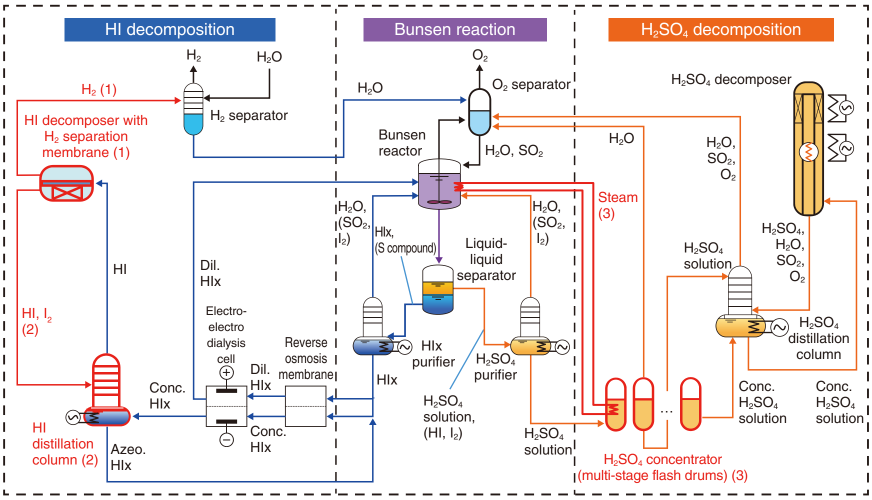
# 6–5 Improving Hydrogen Production Efficiency Using Innovative Technologies

## —High-Efficiency Process Design of the Thermochemical IS Process—




HI decomposition : $2HI \rightarrow H_2 + I_2$

Bunsen reaction : $I_2 + SO_2 + 2H_2O \rightarrow 2HI + H_2SO_4$

$H_2SO_4$ decomposition : $H_2SO_4 \rightarrow H_2O + SO_2 + 0.5O_2$

**Fig.6-10 Flow diagram of the iodine-sulfur (IS) process**

Innovative technologies are shown in red: (1) HI decomposer with membrane for $H_2$ separation, (2) direct feed of gas phase HI and $I_2$ into the HI distillation column, and (3) heat recovery from the Bunsen reaction by depressurized flash $H_2SO_4$ concentration, where HIx denotes a mixture of HI, $I_2$, and $H_2O$, minor compounds are within parentheses, Conc. represents concentrated, Dil. represents dilute, and Azeo. represents pseudo-azeotropic.

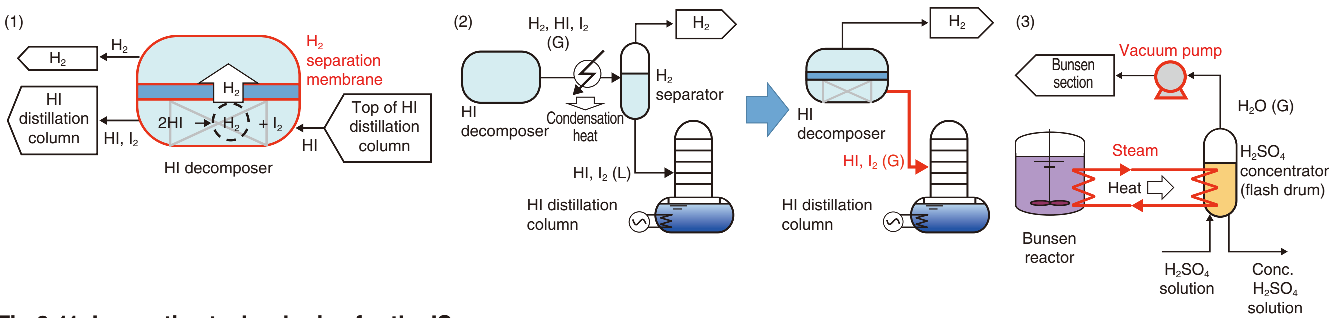



**Fig.6-11 Innovative technologies for the IS process**

(1) Promotion of HI decomposition by membrane separation of $H_2$ in an HI decomposer, (2) change from abandonment of HI and $I_2$ condensation heat to separate $H_2$ (left figure) to condensation heat recovery to the HI distillation column by feeding gas-phase HI and $I_2$ (right figure) and (3) heat recovery from the Bunsen reaction to the depressurized flash $H_2SO_4$ concentration. The excess amount is reduced by (1) and waste heat is recovered by (2) and (3).

The iodine-sulfur (IS) thermochemical hydrogen ($H_2$) production process was investigated as to utilize heat from the High Temperature Gas-cooled Reactors. The IS process, depicted in Fig.6-10, consists of the Bunsen reaction to produce hydrogen iodide (HI) and sulfuric acid ($H_2SO_4$) ($I_2 + SO_2 + 2H_2O \rightarrow H_2SO_4 + 2HI$), HI decomposition to produce $H_2$ ($2HI \rightarrow H_2 + I_2$), and $H_2SO_4$ decomposition to produce oxygen ($O_2$) ($H_2SO_4 \rightarrow H_2O + SO_2 + 0.5O_2$). Overall, water is decomposed to produce $H_2$ and $O_2$.

Practical, competitive implementation of $H_2$ production using the IS process requires improving the efficiency of the process for cost reduction. However, excess material flow is required due to the low reaction ratio, and the exothermic Bunsen reaction and material condensation generate large amounts of excess heat. As such, a high efficiency is difficult to achieve.

As such, technologies to improve the IS process efficiency have been investigated. A HI decomposition ratio higher than reaction equilibrium (44% vs 21%, respectively) was achieved by promoting the reaction using a membrane for $H_2$ separation in the HI decomposer, thus reducing the material flow in the decomposer by 52% (Fig.6-11(1)). To recover waste heat from the condensation of HI and iodine ($I_2$), they were directly fed into the HI distillation column, as vapor–liquid $H_2$ separation is not needed by $H_2$ membrane separation in the HI decomposer (Fig.6-11(2)). To recover the heat of the Bunsen reaction, previously ignored due to its low temperature (378 K), it was used in the multi-stage $H_2SO_4$ concentration flash drums by lowering boiling temperature (368 K) by depressurization with a vacuum pump (Fig.6-11(3)).

A chemical process including these technologies was designed and simulated to estimate the heat demand. Overall, the $H_2$ production efficiency increased from 40% to 50%. Further work on the IS process components is to reduce $H_2$ production cost based on the improved process design.

**Reference**

Kasahara, S. et al., Conceptual Design of the Iodine-Sulfur Process Flowsheet with more than 50% Thermal Efficiency for Hydrogen Production, Nuclear Engineering and Design, vol.329, 2018, p.213–222.