

THERMOLYSIS

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Keywords: Thermolysis of water, direct water decomposition, membrane separation, quenching, high temperature

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In the direct thermal splitting of water, which requires temperature in excess of 2500 K, the recombination of active gaseous products is prevented by rapid quenching of gaseous products or by *in situ* membrane separation of hydrogen and/or oxygen at high temperature.

1. Thermolysis and Direct Thermal Decomposition

Pressure (atm)	Temperature (K)	K _a	Mole fraction of H
0.1	1000	6.75×10^{-10}	2.09×10^{-6}
0.1	2000	3.57×10^{-3}	7.39×10^{-2}
0.1	3000	6.84×10^{-1}	6.67×10^{-1}
0.1	4000	9.53	6.67×10^{-1}
1.0	1000	6.75×10^{-10}	1.21×10^{-6}
1.0	2000	3.57×10^{-3}	3.58×10^{-2}
1.0	3000	6.84×10^{-1}	6.46×10^{-1}
1.0	4000	9.53	6.67×10^{-1}

Table 1. Thermal splitting equilibrium data for water.

Table 1 gives the equilibrium constant, conversion, and mole fraction of hydrogen produced as a function of pressure and temperature. The mole fraction of water in a stoichiometric mixture of hydrogen and oxygen under thermodynamic equilibrium is shown in Figure 1 as a function of temperature and pressure. An appreciable amount of water dissociation can be obtained at very high temperatures, of the order of 2000–3000 K. At a pressure of 101.3 kPa the hydrogen mole fraction at equilibrium is 0.036 at 2000 K. By increasing the temperature to 3000 K, the hydrogen mole fraction is about 0.2 at the same pressure. Thus, the primary heat source at as high temperature as possible is preferable for one-step direct water decomposition. Such temperatures can be

reached by concentrating solar energy or by the fusion reactor. In order to produce hydrogen by direct water decomposition at lower temperature than turning temperature, work equal to ΔG is required to be supplied to the system as the separation work of hydrogen or oxygen from the gaseous products.

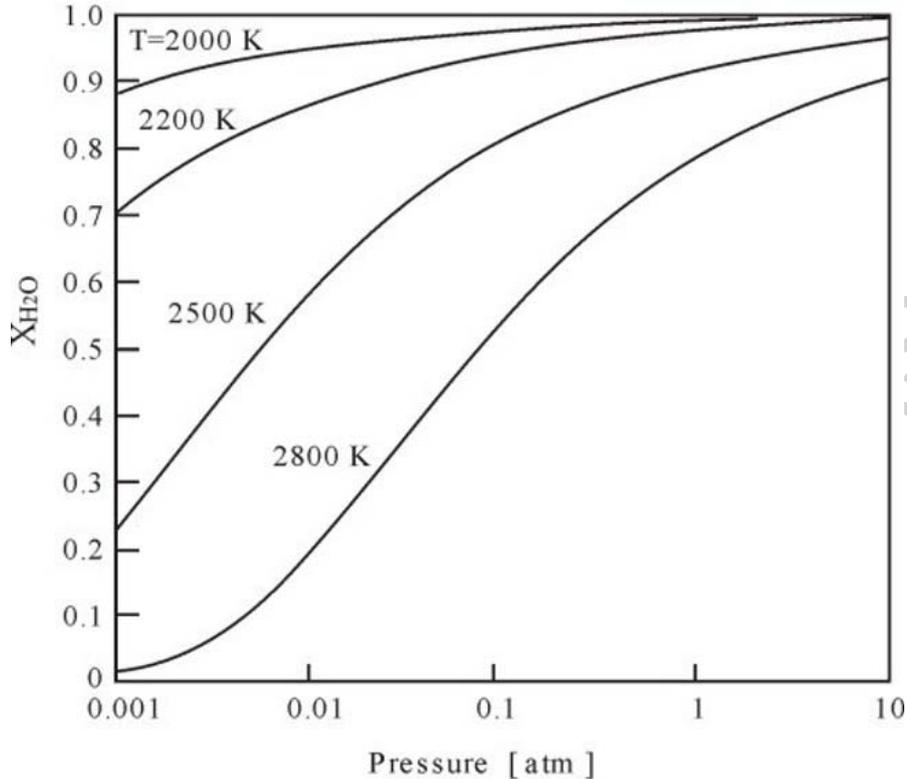


Figure 1. Thermal water splitting

There are two different methods to achieve direct water decomposition preventing the recombination of active species back to water:

1. Decomposition at high temperature followed by quenching of product gases and separation of hydrogen at low temperature. In this process, the recombination of product gases, mainly hydrogen with oxygen, is prevented by a rapid quenching of the product gases from the decomposition temperature of 2000–3000 K to a temperature of 400–800 K. The quenching speed is 10^5 – 10^6 K s⁻¹. This can be achieved by mixing the product gases with cold water or gas. Decomposition and separation of product gases at high temperature using separation membranes. In this case, the decomposition reactor is fabricated, in part, using semi-impermeable high temperature materials. The enrichment of hydrogen or oxygen using simple membranes or the enrichment of both hydrogen and oxygen using double membranes are the possibilities. A solar thermal water-splitting reactor using a porous ceramic membrane is shown in Figure 2. Hydrogen is separated from the mixture of water-splitting products by gas diffusion through a porous zirconium membrane.

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Bibliography

Bilgen E. (1984). Solar hydrogen production by direct water decomposition process: a preliminary engineering assessment. *International Journal of Hydrogen Energy* **9**(1/2), 53.

Bilgen E., Ducarroir M., Foex M., Silieude F., and Trombe F. (1977). Energy for direct use of solar t and two-step water decomposition cycles. *International Journal of Hydrogen Energy* **2**, 251.

Ihara S. (1978). Feasibility of hydrogen production by direct water splitting at high temperature. *International Journal of Hydrogen Energy* **3**, 287.

Ihara S. (1980). On the study of hydrogen production from water using solar thermal energy. *International Journal of Hydrogen Energy* **5**, 527.

Kogan A. (1997). Direct solar thermal splitting of water and on-site separation of the products—I. Theoretical evaluation of hydrogen yield. *International Journal of Hydrogen Energy* **22**(5), 481.

Kogan A. (1998). Direct solar thermal splitting of water and on-site separation of the products—II. Experimental feasibility study. *International Journal of Hydrogen Energy* **23**, 89, Kogan A.,

Spiegler E., and Wolfshtein M. (2000). Direct solar thermal splitting of water and on-site separation of the products—III. Improvement of reactor efficiency by steam entrainment. *International Journal of Hydrogen Energy* **25**, 739.

Biographical Sketch

Atsushi Tsutsumi, born November 2, 1956, in Japan, is an associate professor of Chemical System Engineering at University of Tokyo. He received his Doctorate of Engineering from University of Tokyo in 1986. He has been active in research on innovative thermochemical energy technology and nonlinear dynamics and chaos scale-up methodology development for multi-phase reactors for last ten years. He has over 70 scientific publications and 100 proceedings in international journals and conferences.