水素還元による月土壌からの水製造

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Introduction

Background

On going Lunar Exploration Projects of Japan

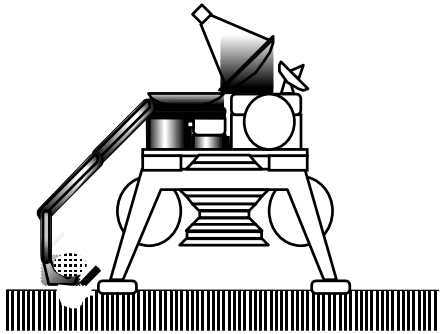
⇩ - *SELENE, LUNAR-A*

Utilization of Lunar Environment and Resources

⇩ - *Solar Power, Lunar Soil*

Essential technologies for space development

- *From Moon to Mars…*



Purposes of this study

1. To discuss the possibility of water production
2. To seek the optimum reaction conditions
3. To Investigate the reaction mechanism of water production

Lunar soil simulant

✧Experiments in the laboratory ⇒ Lunar Soil Simulant

*Lunar Soil Simulant is made by Shimizu Corporation, Japan.

Characteristics of Lunar Soil Simulant

◆Compositions [wt%]

component	Lunar Soil (Apollo14)	Lunar Soil Simulant	Earth (reference)
SiO_2	48.10	50.28	60~70
Al_2O_3	17.40	16.32	-
Fe_2O_3	0.00	4.42	10~12
FeO	10.40	8.7	4~5
Others	23.70	20.28	-
sum	99.60	100.00	-

◆Median diameter

70 μm (weight base)

*Lunar soil does not contain any Fe_2O_3.

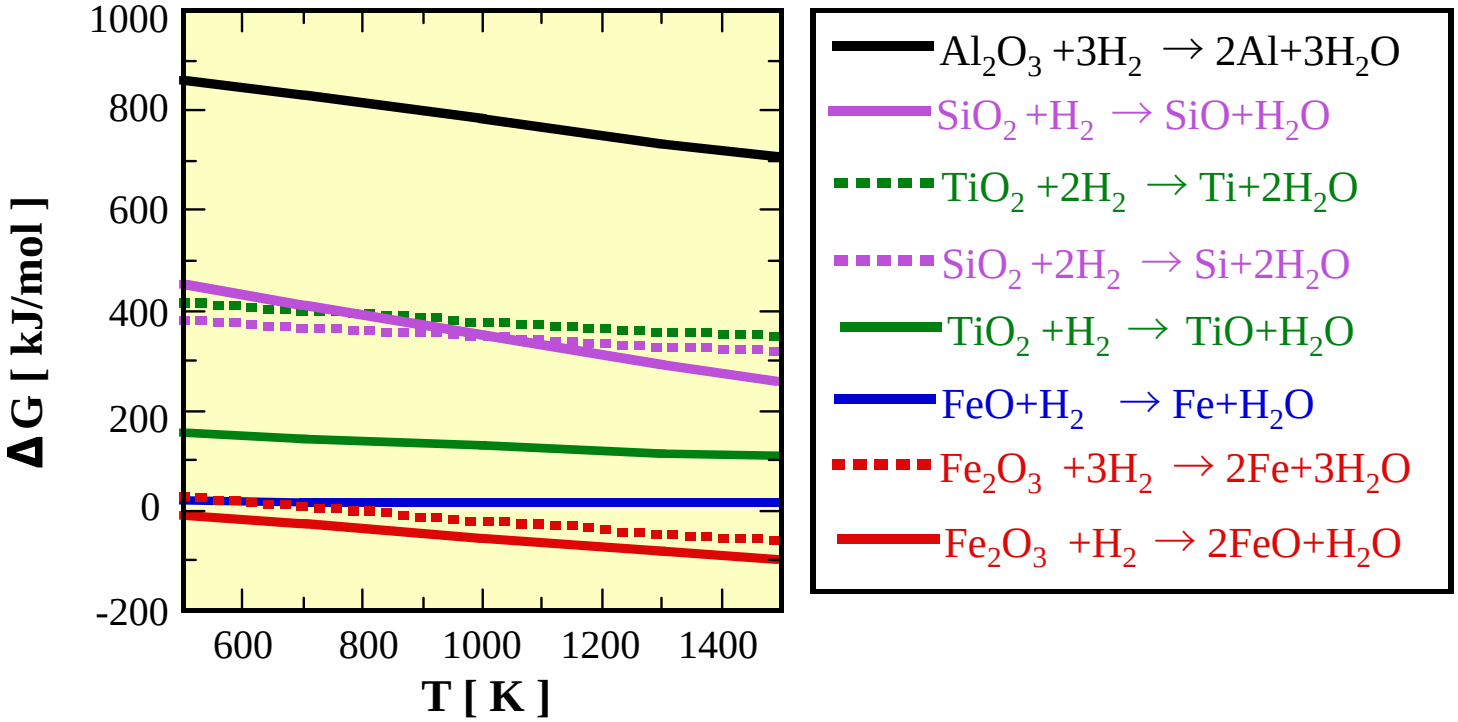
*Lunar soil simulant has almost same compositions of lunar soil.

Thermodynamic consideration

Hydrogen Reduction of Lunar Soil Simulant

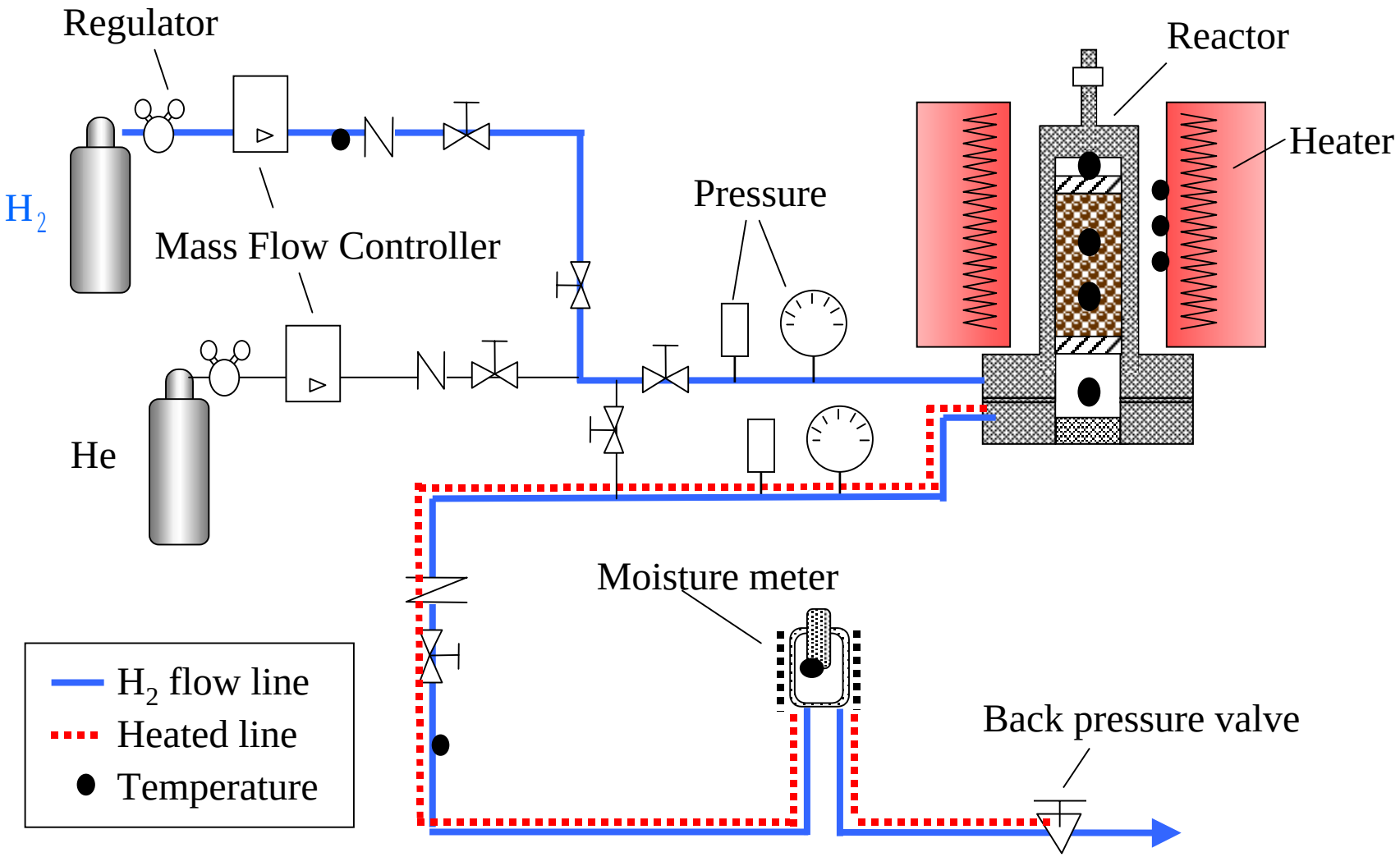
Minerals + $H_2 \rightarrow$ Metal + H_2O

· Free energy formation for hydrogen reduction

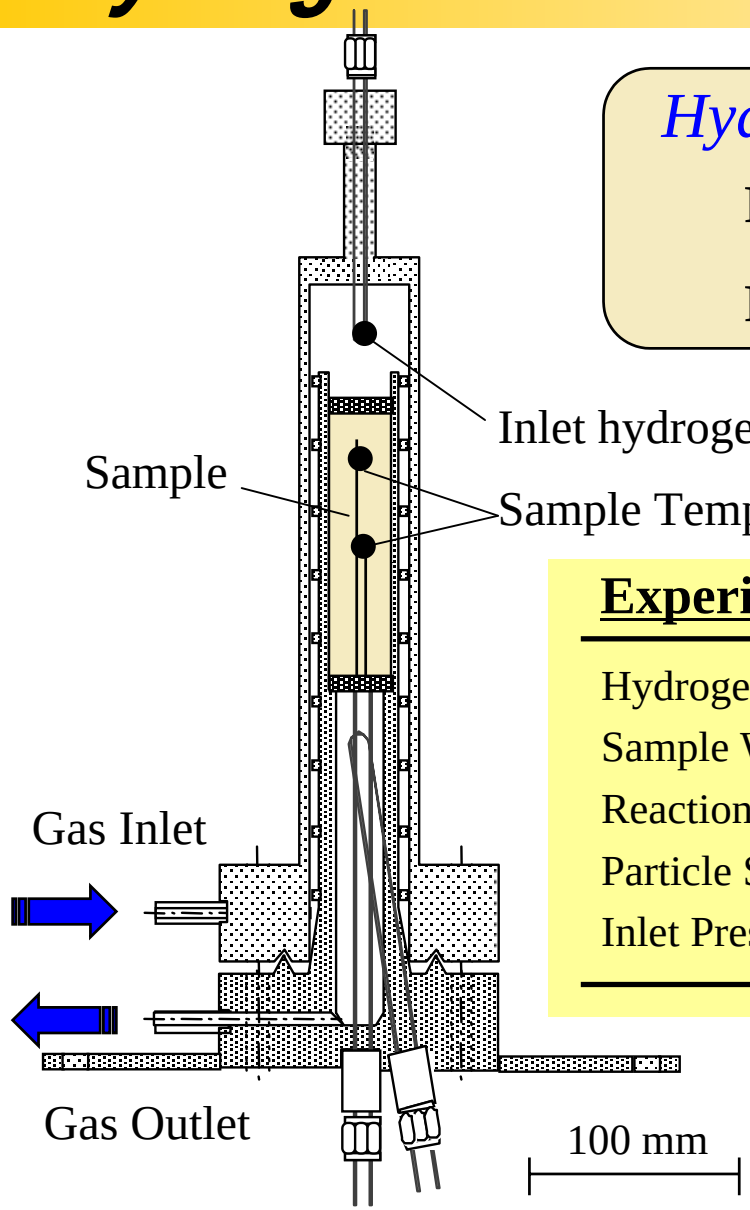


✓Ferrous oxide and ferric oxide can be easily reduced by hydrogen.

Experimental apparatus



Hydrogen reduction reactor



Hydrogen Reduction of Iron Oxide

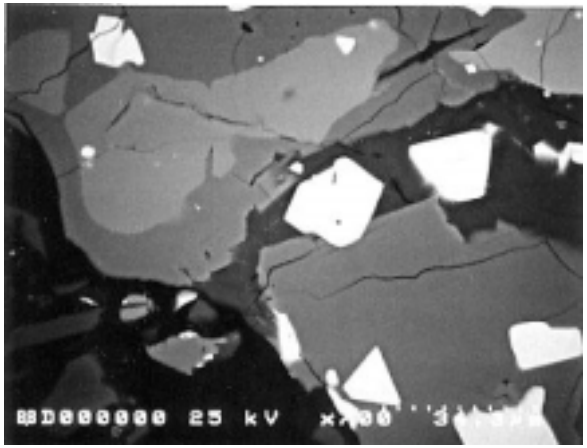
$$Fe_2O_3 + H_2 \rightarrow 2FeO + H_2O \quad (1)$$

$$FeO + H_2 \rightarrow Fe + H_2O \quad (2)$$

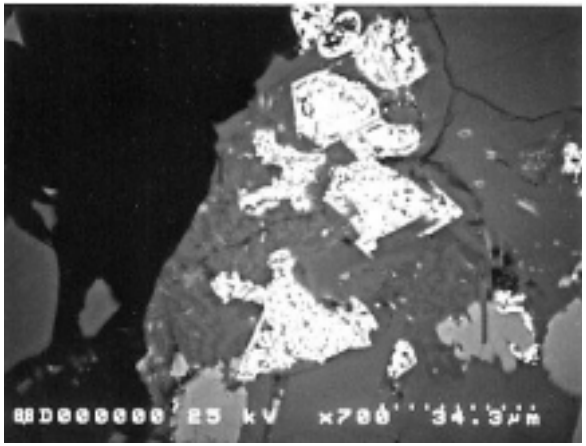
Experimental Conditions

Hydrogen Flow Rate	[SLM]	4 (3.57×10^{-1} g/min)
Sample Weight	[g]	20, 40, 60
Reaction Temperature	[K]	1173, 1223, 1273, 1323
Particle Size	[μm]	Entire, Under75μm, Over75μm
Inlet Pressure	[kPa]	303, 404, 505

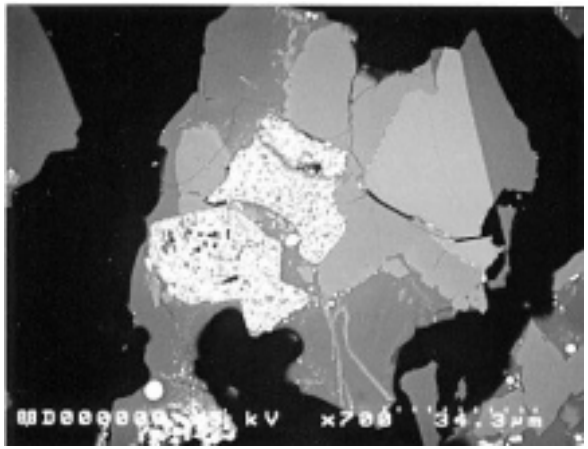
SEM analysis



Before Reduction



After Reduction
at 1273 K



After Reduction
at 1323 K

As reduction proceeds…

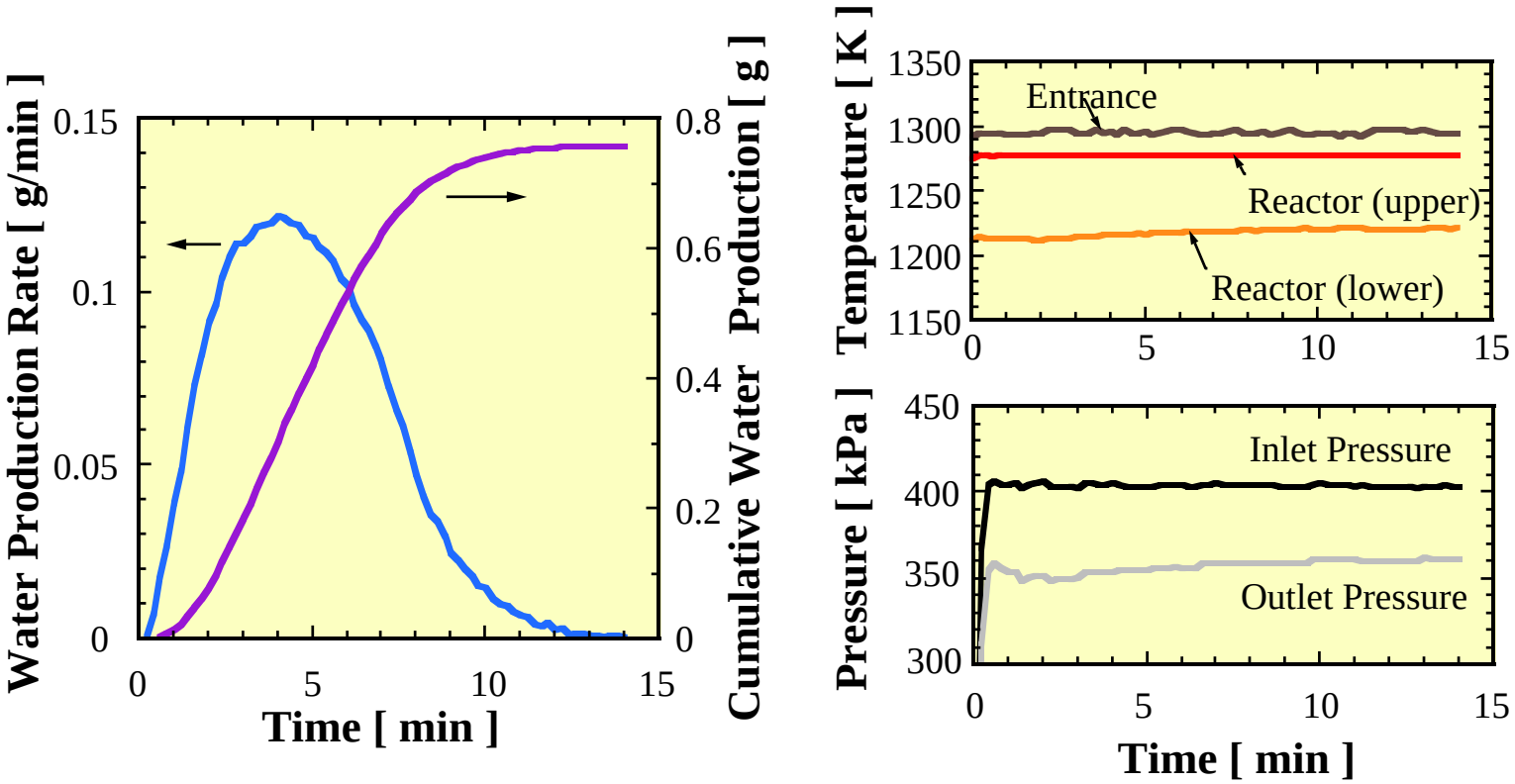
✓Bright parts (ilmenite) have several holes.

✓At 1323 K, the pores were blocked by the melt of alkali contents.

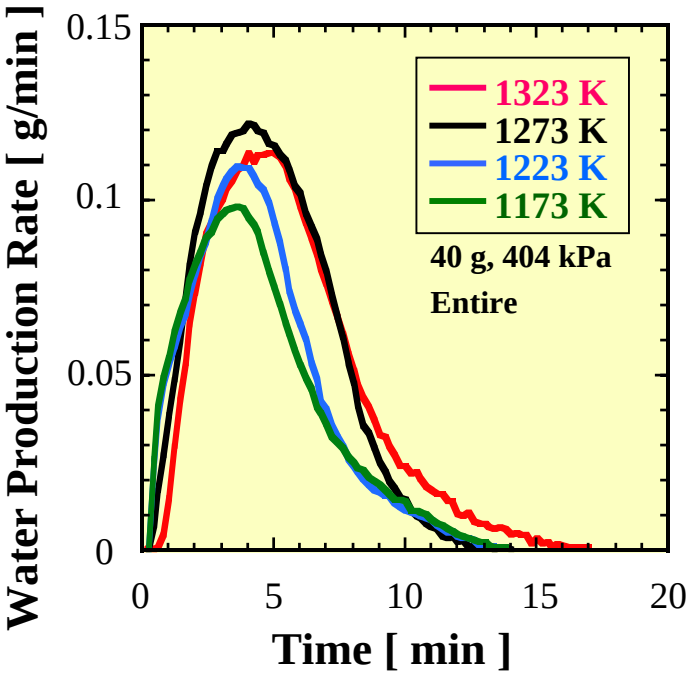
Results of hydrogen reduction

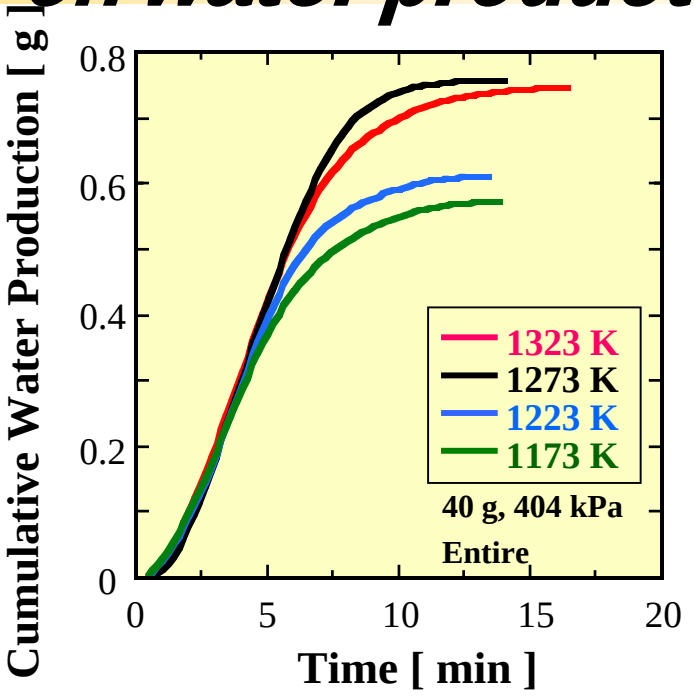
Experimental Conditions

Simulant 40 g, 4 l/min, 1273 K, 404 kPa



Effect of reaction temperature on water production





Increase in temperature up to 1273 K

⇒ Increase in produced water

Over 1273 K

The pores were blocked by the melt of alkali contents.

Composition change during reduction

[wt%]

component	Before	2 min	6 min	After
SiO_2	50.90	51.13	51.30	51.10
Al_2O_3	16.00	16.11	16.22	15.96
TiO_2	2.11	2.11	2.19	2.11
Fe	0.11	1.56	3.47	3.86
Fe_2O_3	4.25	1.07	0.07	0.07
FeO	8.47	9.53	7.95	8.15

Hydrogen Reduction of Iron Oxide

$$\mathbf{Fe_2O_3 + H_2 \rightarrow 2FeO + H_2O} \quad (1)$$

$$\mathbf{FeO + H_2 \rightarrow Fe + H_2O} \quad (2)$$

Reaction Rate (1) >> (2)

Why water production by hydrogen reduction?

1. Reaction mechanism is simple.
   - > Just one step of reaction
   - > Technology readiness
2. Transportation from the earth costs low.
   - > Hydrogen is light
3. Process conditions is not so severe.
   - > Temperature
   - > Energy
   - > Plant mass