§3. Advancement of Water-Hydrogen Chemical Exchange Apparatus by Introducing Trickle Bed Reactor

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Experimental studies on hydrogen isotope separation by a Combined Electrolysis Catalytic Exchange (CECE) have been carried out in order to apply it to the system of water detritiation for fusion reactors.

In the present study we try to improve the separative performance of the CECE process by developing effective trickle beds.

i) Experiments

The reactor column is a Pyrex glass tube with 25 mm internal diameter and 60 cm length. The column is filled with Kogel catalysts (0.8 wt% Pt deposited) and Dixon gauze rings in two ways. One is the layered bed where layers of Kogel catalysts and that of Dixon gauze rings are filled in the column alternately. The other is the homogeneous bed where Kogel catalysts and Dixon gauze rings are mixed and filled in the column homogeneously. These packed beds are shown in Fig. 1.

Hydrogen-deuterium isotope separation with the CECE equipment was performed at 101 kPa, 343 K. Flow rate of hydrogen gas was selected to 4, 8 and 12 L/min. Feed rate of distilled water was adjusted respectively as the molar flow ratio of hydrogen gas to feed water became the same value in all tests. The concentrations of HD or HDO in gas and liquid samples were measured using a stable isotope ratio mass spectrometer (MAT252, Thermo Finnigan) with a relative accuracy to 1 %.

ii) Separation factors of the packed beds

Separation factor of the water phase α and that of the hydrogen gas phase β are defined as follows with the molar concentration of deuterated molecule C and the molar flow ratio F:

$$\alpha = C_{(\text{Feed})}/C_{(\text{Extracted water})}, \quad \beta = C_{(\text{Extracted hydrogen gas})}/C_{(\text{Feed})},$$

$$C_{(\text{Feed})} = \frac{F_{(\text{Feed water})}C_{(\text{Feed water})} + F_{(\text{Feed hydrogen gas})}C_{(\text{Feed hydrogen gas})}}{F_{(\text{Feed water})} + F_{(\text{Feed hydrogen gas})}}$$

Calculated separation factors are summarized in Table I. The α values of the both packed beds keep almost constant values of about two in the present range of hydrogen flow rate. The values of the homogeneous bed are slightly larger than that of the layered bed. On the other hand the β values of the homogeneous bed are about twice as large as that of layered bed. In either case the results indicate that the homogeneous bed is more efficient than the layered bed.

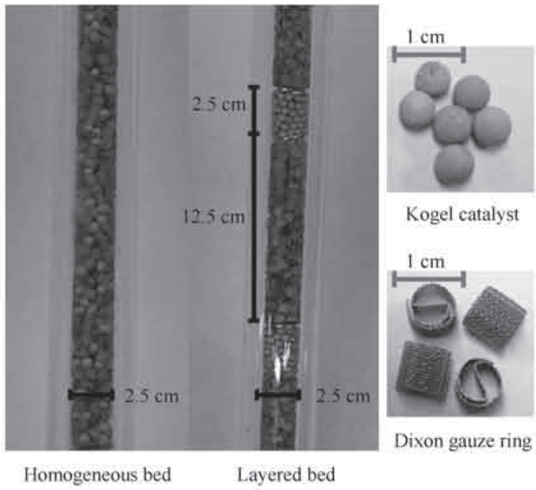

Fig. 1: Two types of packed beds

Table I: Separation factors of the packed beds

	α			β		
F [L/min]	4	8	12	4	8	12
Homogeneous	2.27	2.22	2.12	6.00	5.51	4.80
Layered	2.01	1.88	1.91	3.14	2.63	2.45

iii) Mass transfer coefficients of the homogeneous bed

In the case of homogeneous packed bed deuterium mass transfer coefficient between hydrogen gas and water vapor k_g and that between water vapor and liquid water k_l can be obtained from a simultaneous solution of material balances represented the mass transfer process. Calculated values are summarized in Table II.

The values previously reported were in the range 100-350 kmol/m^3/h for k_g and 40-280 kmol/m^3/h for k_l. The value of k_l is much improved in our experiments. This fact indicates that the homogeneous packed bed of Kogel catalyst and Dixon gauze ring is promising for one of the candidate column.

Table II: Mass transfer coefficients of the homogeneous bed

F [L/min]	4	8	12
k_g [kmol/m^3/h]	89	147	181
k_l [kmol/m^3/h]	300	639	926

Reference

1) Sugiyama, T., Asakura, Y., *et al.*: *Fusion Sci. Technol.*, 48 [1], pp. 132-135 (2005).
2) Sugiyama, T., Asakura, Y., *et al.*: *ISFNT-7*, P1-33, Tokyo, May (2005).