Highly effective hydrogen isotope separation through quantum sieving

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Tritium plants represent integral facilities in controlled nuclear fusion energy systems, performing tritium breeding, extraction, purification, storage, and recycling. Hydrogen isotope separation constitutes a core technology within these plants, with its functionality spanning the deuterium-tritium inner fuel cycle, outer fuel cycle, and tritium safety containment systems. This technology critically governs the fusion reactor's tritium self-sufficiency and operational safety. Conventional separation techniques—including cryogenic distillation (CD), Girdler-Sulfide processes, membrane separation, electrolysis, thermal diffusion, chromatography, and thermal cycling absorption purification (TCAP)—exhibit inherent limitations such as low separation efficiency and high energy consumption. Recently, hydrogen isotope separation via quantum sieving in porous materials has emerged as a promising frontier due to its ultrahigh selectivity. This work comprehensively reviews field advancements and details our research group's recent progress in: (1) establishing a quantum sieving separation research platform, (2) fabricating high-efficiency separation materials, and (3) experimentally validating deuterium-tritium separation feasibility.

Keywords: Tritium plant; Hydrogen isotope separation, Chemical affinity quantum sieving, Kinetic quantum sieving

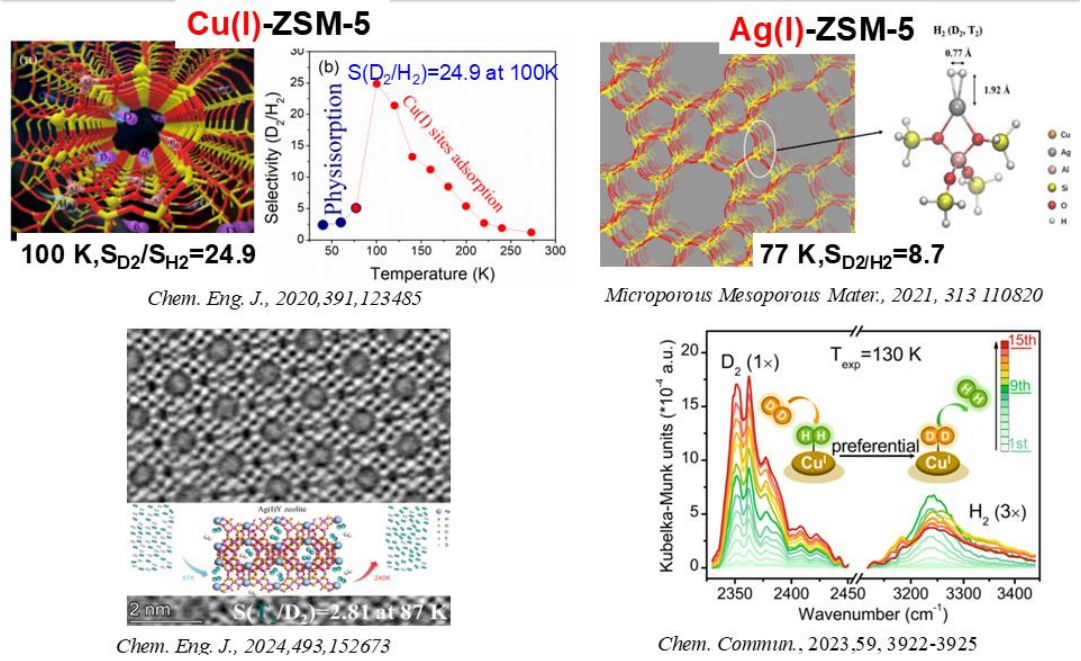

Fig.1 Hydrogen isotope separation via quantum sieving in our research group

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