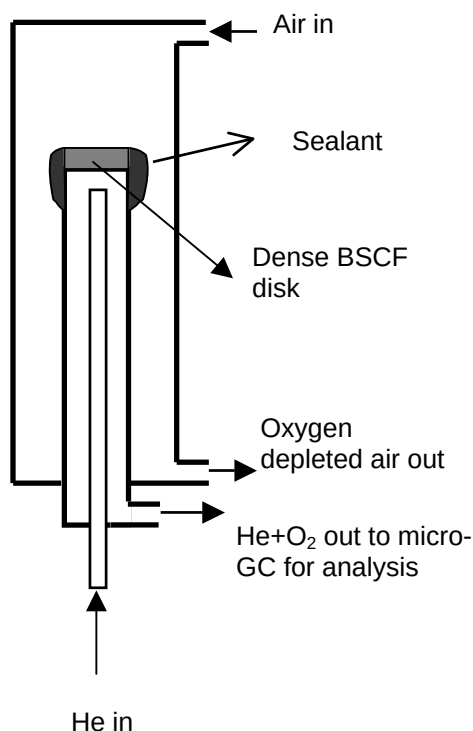




Supplementary Figure. 7 Reactor configuration for measurement of oxygen permeation flux. A dense, disk-shaped BSCF membrane, with thickness 1.0-1.2 mm and diameter ~13 mm, was mounted onto the end of a quartz tube using an appropriate sealant, which was also applied to the sidewalls of the membrane so as to eliminate leakage through the sample edges. High temperature experiments (775 – 900°C): Extensive measurements at high temperatures were carried out to enable independent determination of D_V and k_a (S8). A ceramic paste served as the sealant, leaving an exposed surface area of 0.72 cm². One side of the membrane, the oxygen-poor side, was exposed to helium at varied flow rates (5-120 ml.min⁻¹, STP). The other, oxygen-rich side of the membrane was exposed to air at a flow rate of 100 ml.min⁻¹ [STP].

Low temperature experiments (390 – 690°C): Low

temperatures measurements were limited to a smaller range of experimental conditions because of the tendency of BSCF to become reduced under prolonged exposure to helium at temperatures $\leq 700^\circ\text{C}$, but the results, nevertheless, provide insight as to transport mechanisms (S9). A silver paste served as the sealant, leaving an exposed surface area of 1.0 cm². The oxygen-poor side of the membrane was exposed to helium at a single flow rate of 50 ml.min⁻¹ [STP], whereas the oxygen-rich side was exposed to air at a flow rate of 50 ml.min⁻¹ [STP]. For both sets of experiments, the exit gas from the oxygen-poor side was directed to a GC equipped with a 5 Å molecule sieve for gas composition analysis (HP 5890 II for high temperature experiments, and Varian CP 4900 micro-GC for low temperature experiments). The oxygen permeation flux was calculated according to the equation:

$$J_{\text{O}_2} (\text{ml.cm}^{-2}.\text{min}^{-1}, \text{STP}) = [C_{\text{O}_2} - C_{\text{N}_2} \times 0.21/0.79] \times (28/32)^{1/2} \times F/S$$

where C_{O_2} and C_{N_2} are the measured concentrations of oxygen and nitrogen, respectively, in the gas on the oxygen-poor (helium sweep) side, F the flow rate of this gas (ml.min⁻¹, STP), and S the exposed membrane area (cm²). This formalism, through the measurement of nitrogen, allows one to correct for leaks across the seals, however, in most cases, no nitrogen was detected. The oxygen partial pressure (P_{O_2}) in the exhaust from the oxygen-poor (helium sweep) side was obtained assuming ideal gas behavior, that is

$$P_{\text{O}_2} = C_{\text{O}_2} \times P$$

where P is total pressure in the exhaust gas, measured with a pressure sensor.