

## 1. Catalyst characterization

N<sub>2</sub> adsorption–desorption isotherms were measured on a Beckman Coulter's SA3100 automatic analyzer at -196 °C. Samples were maintained at 300 °C for 3h for pre-treatment before N<sub>2</sub> sorption measurements, and the BET surface areas of the samples were measured using the BET method according to the data of the adsorption branch. X-ray powder diffraction (XRD) patterns were recorded using a Rigaku D/Max-1200 diffractometer equipped with Cu K $\alpha$ -radiation ( $\lambda$  = 0.154056 nm) operating at 40 kV and 30 mA. The samples were analyzed in the 2 $\theta$  range of 5–90° with a scanning speed of 2°/min. The crystalline phases of the samples were determined by comparison using Jade 6.5 software. Raman spectra were measured using a Thermo Scientific DXR confocal Raman microscope using a 532 nm excitation laser. Temperature-programmed reduction of hydrogen (H<sub>2</sub>-TPR) was conducted on an apparatus equipped with a TCD detector to measure the reactive surface sulfur species. Prior to H<sub>2</sub>-TPR measurement, 50 mg of samples were pre-treated with argon flow (Ar, 30 ml·min<sup>-1</sup>) at 400 °C for 1 h before being cooled to 100 °C. Subsequently, a mixture of 10 vol% H<sub>2</sub>/Ar (30 ml·min<sup>-1</sup>) was introduced, and the pre-treated samples were heated at a rate of 10 °C·min<sup>-1</sup> to 900 °C. Temperature-programmed desorption of reactants (CO/H<sub>2</sub>/H<sub>2</sub>S-TPD) was conducted in a fixed-bed flow reactor equipped with a thermal conductivity detector (TCD) and flame photometric detector (FPD). Prior to CO/H<sub>2</sub>/H<sub>2</sub>S-TPD measurements, 50 mg of samples were pretreated by flowing helium (He, 30 ml min<sup>-1</sup>) at 300 °C for 30 min before being cooled to 30 °C. The gas stream was switched to 10% CO/He, H<sub>2</sub>/Ar, and H<sub>2</sub>S/He (v/v, 20 mL/min), respectively. Adsorption was carried out at 30 °C for 1 h and then purged with pure He to remove physically adsorbed CO/H<sub>2</sub>/H<sub>2</sub>S. The reactor was heated from 30 °C to 900 °C at a rate of 10 °C /min under He flow.

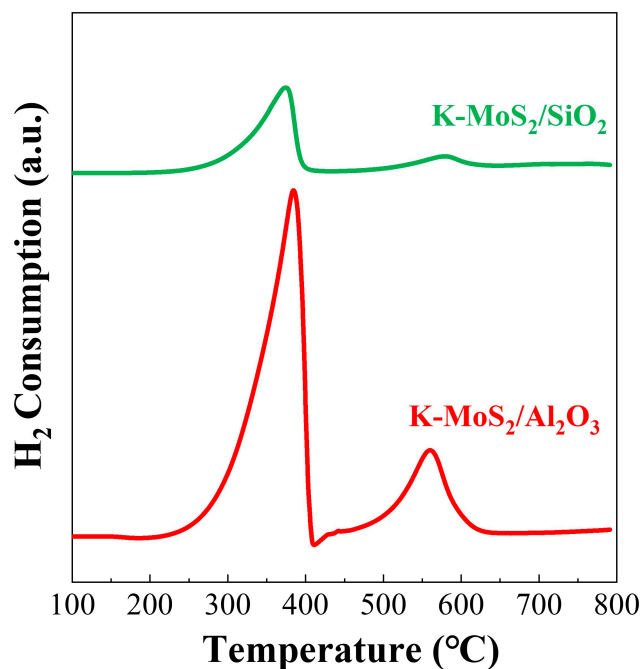


Figure S1. H<sub>2</sub>-TPR curves of K-MoS<sub>2</sub>/SiO<sub>2</sub> and K-MoS<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>.