Stable high-pressure phases in the H-S system determined by chemically reacting hydrogen and sulfur

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Synchrotron X-ray diffraction and Raman spectroscopy have been used to study chemical reactions of molecular hydrogen with sulfur at high pressures. We find theoretically predicted *Cccm* and *Im*-3*m* H_3S to be the reaction products at 50 and 140 GPa, respectively. *Im*-3*m* H_3S is a stable crystalline phase above 140 GPa and it transforms to *R3m* H_3S on pressure release below 140 GPa. The latter phase is (meta)stable down to at least 70 GPa where it transforms to *Cccm* H_3S upon annealing (T<1300 K) to overcome the kinetic hindrance. *Cccm* H_3S has an extended structure with symmetric hydrogen bonds at 50 GPa and upon decompression it experiences a transformation to a molecular mixed H_2S-H_2 structure below 40 GPa without any apparent change in the crystal symmetry.