Towards Ambient Superconductivity: Novel Hydrogen-Rich Materials

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One of the long-standing challenges in experimental physics is the observation of room-temperature superconductivity (RTSC). Recently, high-temperature conventional superconductivity in hydrogen-rich materials has been reported in several systems under high pressure. An important discovery leading to RTSC is the pressure-driven disproportionation of hydrogen sulfide ($H_2S$) to $H_3S$, with a confirmed transition temperature of 203 kelvin at a very extreme pressure of 155 gigapascals. I will show that $CH_4$ readily mix with $H_2S$ and hydrogen to form guest–host structures at lower pressures, and are of comparable size at 4 gigapascals. By introducing methane at low pressures into the $H_2S + H_2$ precursor mixture for $H_3S$, molecular exchange is allowed within a large assemblage of van der Waals solids that are hydrogen-rich with $H_2$ inclusions; these guest–host structures become the building blocks of a room temperature superconducting compound at extreme pressures. Furthermore, I will present our work on metal superhydrides, using a direct combination of the elements to synthesize yttrium superhydride, which demonstrates conventional superconductivity at 262 K and is in excellent agreement with density functional structure search and BCS theory calculations.