CLAIMS

1. A method for co-processing H_2S and CO_2 in an electrolyzer that comprises an anode, a cathode, and an electrolyte positioned between and in electrochemical contact with the anode and the cathode, the method comprising:

feeding a first gas stream comprising H_2S to the anode of the electrolyzer;

feeding a second gas stream comprising CO_2 to the cathode of the electrolyzer;

splitting H_2S of the first gas stream into hydrogen and elemental sulfur at the anode;

transferring the hydrogen split from the H_2S of the first gas stream from the anode across the electrolyte to the cathode; and

hydrogenating the CO_2 from the second gas stream with the hydrogen that was transferred from the anode, wherein

the electrolyte is a solid electrolyte; and

the elemental sulfur split from the H_2S does not migrate into the electrolyte and is substantially removed from the anode from the electrolyzer as an anode exhaust stream.

2. The method of claim 1, wherein the CO_2 from the second gas stream is hydrogenated according to a reaction as follows:

$$xCO_2 + (2x - z + y/2)H_2\ (g) \xrightarrow{T,P,catalyst} C_xH_yO_z\ (g) + (2x - z)H_2O\ (g),$$

wherein $C_xH_yO_z$ is selected from the group consisting of methane, ethane, propane, methanol, ethanol, and propanol.

3. The method of claim 2, wherein the CO_2 from the second gas stream is hydrogenated to form water and one of methane and methanol.

4. The method of claim 1, wherein the anode comprises a metal sulfide.

5. The method of claim 1, wherein the anode comprises a member selected from the group consisting of NiS, MoS_2, WS_2, CoS, $Li_2S/CoS_{1.35}$, FeMoS, NiMoS, CoMoS, VO_5, $LiCoO_2$, Pt/TiO_2, Pd, Au, Ag, Ru, Rd, Ir, Nb_2O_5-Ni, BaO-Ni, $Ce_{0.8}Sm_{0.2}O_2$-Ni, $CuFe_2S_4$, $CuNi_2S_4$, $CuCoS_4$, $NiCo_2S_4$, $NiFe_2S_4$, and mixed metal oxides of La, Sr, Mn, Ti, Cr, Ga, Y, V, Fe, Co, Mo, Ce, Mg, Gd, and Ba.

6. The method of claim 1, wherein the electrolyte comprises a member selected from the group consisting of perovskite materials of the general type ABO_3 and $ABMO_3$ that exhibit proton conductivity at temperatures from 600° C. to 1000° C., zirconia- and ceria-based proton conducting electrolytes, and solid acids of $MHXO_4$ and $M_3H(XO_4)_2$, where M is Cs, NH_4, Rb, and X is S or Se.

7. The method of claim 1, wherein CO is added to the first gas stream, and the method further comprises forming carbonyl sulfide.

8. The method of claim 7, wherein the method further comprises feeding the carbonyl sulfide to a decomposer where the carbonyl sulfide is split into elemental sulfur and CO.

9. The method of claim 8, wherein the CO produced in the decomposer by splitting the carbonyl sulfide is the CO added to the first gas stream.

10. The method of claim 1, wherein the second gas stream comprises CO_2 and an additional hydrogen source.

11. The method of claim 10, wherein the hydrogen split from the H_2S of the first gas stream is transferred from the anode across the electrolyte and form promoting species on the cathode.

12. The method of claim 1, wherein the first gas stream comprises H_2S and CO_2 and the method further comprises forming SO_x and CO after the H_2S in the first gas stream is split into hydrogen and elemental sulfur.