In this paper, we address the phenomenon of temporal, self-sustained oscillations which have been observed under quite general conditions in solid oxide fuel cells. Our objective is to uncover the fundamental mechanisms giving rise to the observed oscillations. To this end, we develop a model based on the fundamental chemical kinetics and transfer processes which take place within the fuel cell. This leads to a three-dimensional dynamical system, which, under typical operating conditions, is rationally reducible to a planar dynamical system. The structural dynamics of the planar dynamical system are studied in detail. Self-sustained oscillations are shown to arise through Hopf bifurcations in this planar dynamical system, and the key parameter ranges for the occurrence of such oscillations are identified.