We consider stochastic descriptions of chemical reaction networks in which there are both fast and slow reactions, and for which the time scales are widely separated. We develop a computational algorithm that produces the generator of the full chemical master equation for arbitrary systems, and show how to obtain a reduced equation that governs the evolution on the slow time scale. This is done by applying a state space decomposition to the full equation that leads to the reduced dynamics in terms of certain projections and the invariant distributions of the fast system. The rates or propensities of the reduced system are shown to be the rates of the slow reactions conditioned on the expectations of fast steps. We also show that the generator of the reduced system is a Markov generator, and we present an efficient stochastic simulation algorithm for the slow time scale dynamics. We illustrate the numerical accuracy of the approximation by simulating several examples. Graph-theoretic techniques are used throughout to describe the structure of the reaction network and the state-space transitions accessible under the dynamics. (Received September 17, 2015)