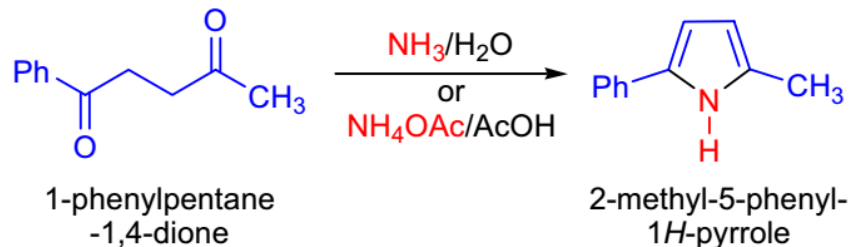
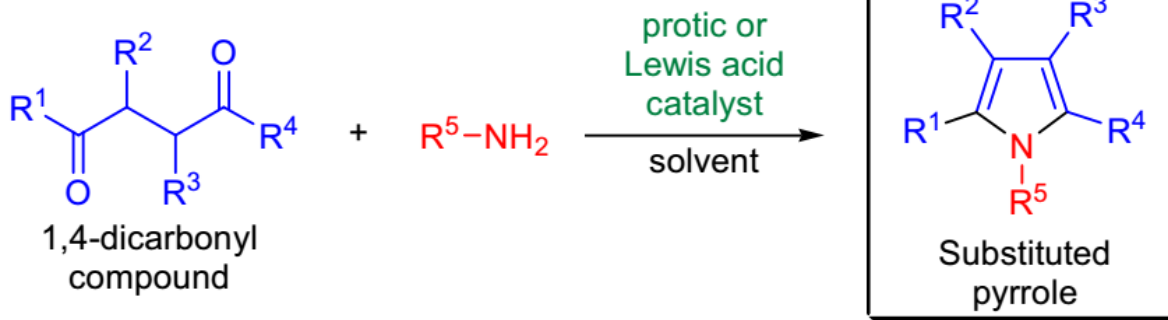
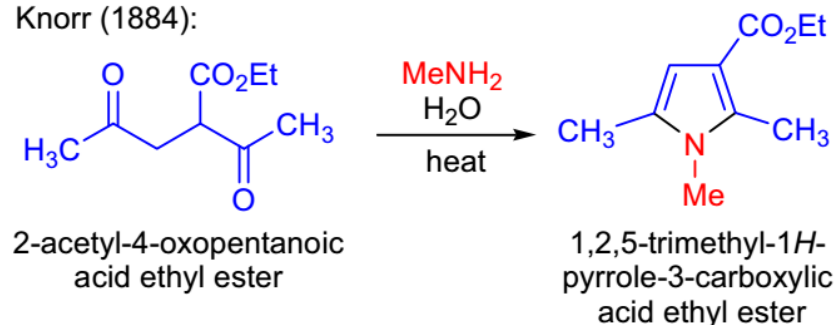


Paal-Knorr Pyrrole Synthesis

Paal (1884):



Knorr (1884):



$R^1 = \text{H, alkyl, aryl}; R^{2-3} = \text{H, alkyl, aryl, CO}_2\text{-alkyl, CO}_2\text{-aryl}; R^4 = \text{H, alkyl, aryl};$

$R^5 = \text{H, } 1^\circ, 2^\circ \text{ or } 3^\circ \text{ alkyl, aryl, heteroaryl, NR}_2, \text{NHR, NH}_2, \text{OH};$

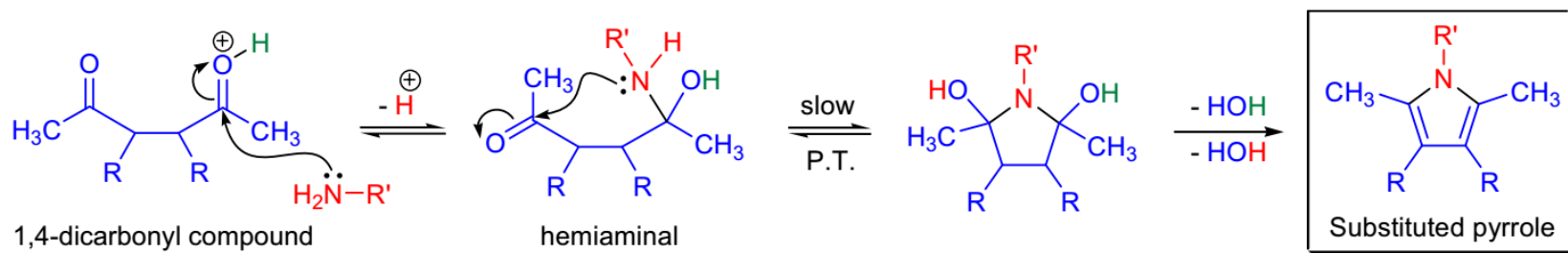
ammonia precursors: $\text{NH}_4\text{OAc, (NH}_4\text{)}_2\text{CO}_3$;

catalyst: zeolite, Al_2O_3 , *p*-TSOH, CSA, zirconium phosphate, $\text{Ti}(\text{O}i\text{-Pr})_4$,

microwave;

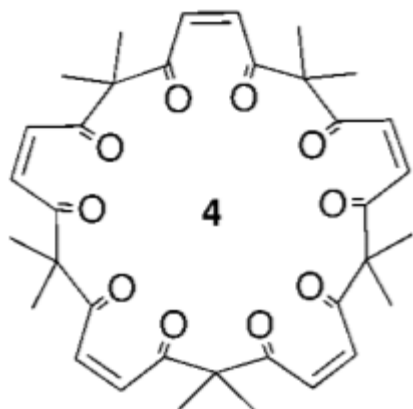
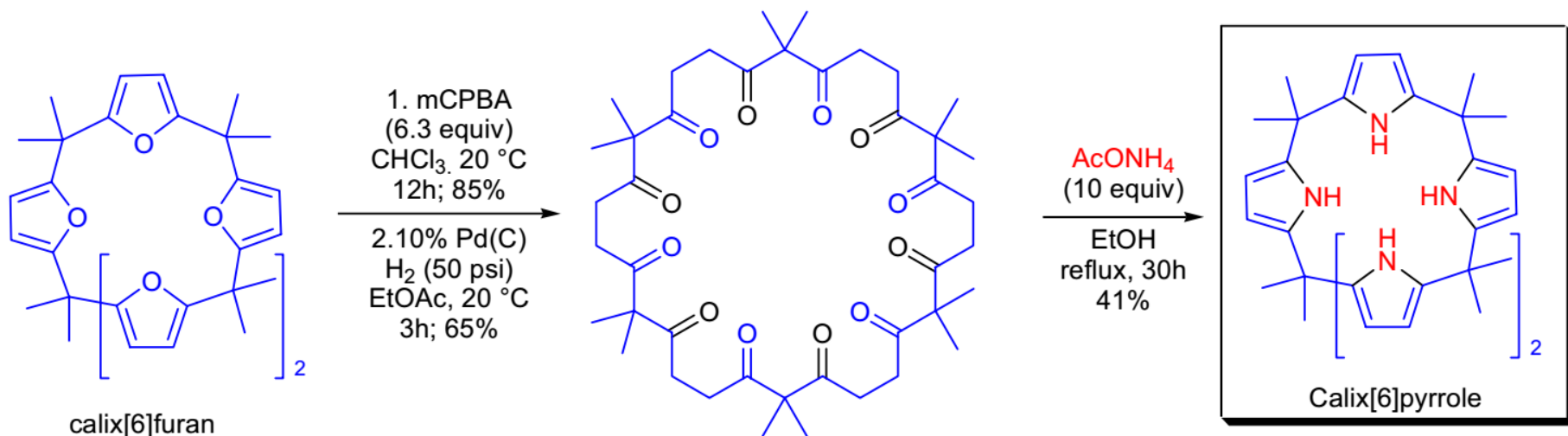
solvent: MeOH, EtOH, H₂O, toluene, DMF, ionic liquid

Mechanism and Features of Paal-Knorr Pyrrole Synthesis

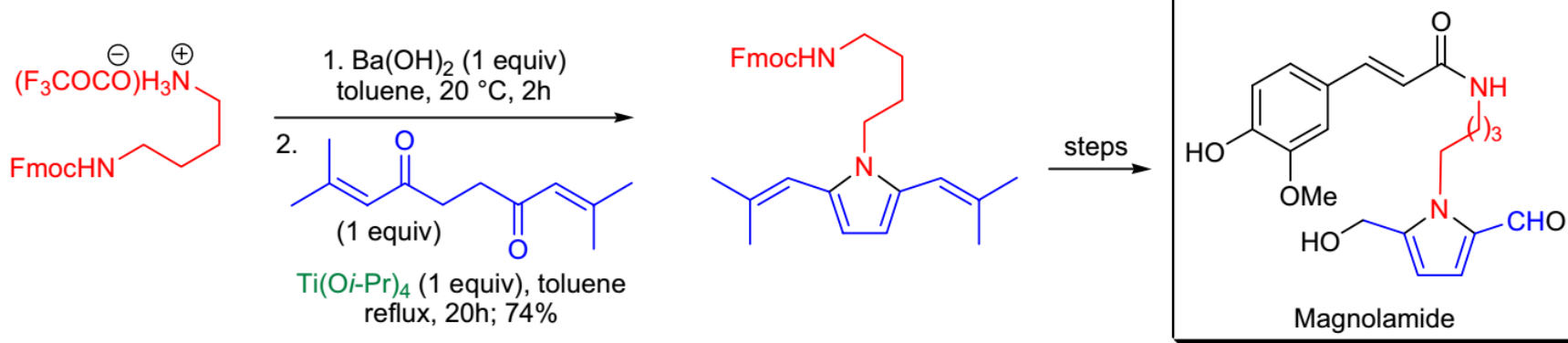
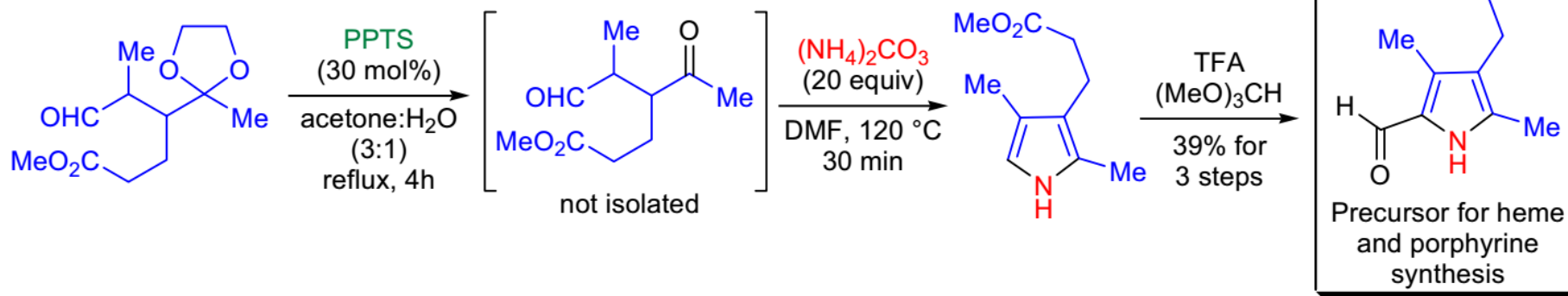
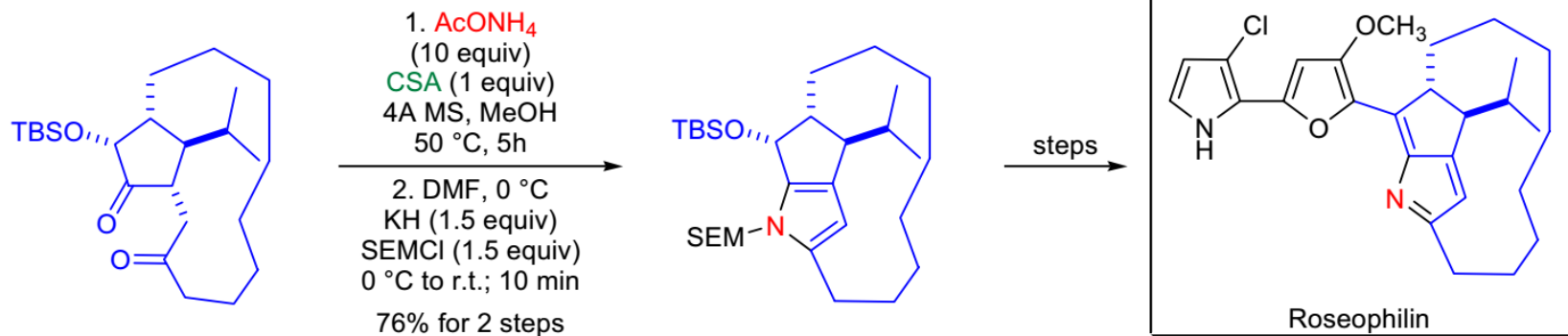


- 1) practically any 1,4-dicarbonyl compound (mainly 1,4-diketones) or their surrogates are good substrates for the reaction;
- 2) the structure of the amine component can be varied widely, since ammonia, aliphatic primary amines, both electron-rich and electron-poor aromatic amines, and heterocyclic amines (e.g., aminopyridines, aminothioazoles, etc.) can be used;
- 3) ammonia can be introduced either as a concentrated aqueous solution, as ammonium acetate in an alcohol solvent or ammonium carbonate in DMF at high temperature;
- 4) besides protic acids, certain Lewis acids such as Ti(Oi-Pr)₄, as well as layered zirconium phosphate also catalyze the reaction;
- 5) the solvent of choice depends on the type of amine used, and it can range from polar protic to dipolar aprotic all the way to nonpolar solvents

Synthetic Applications

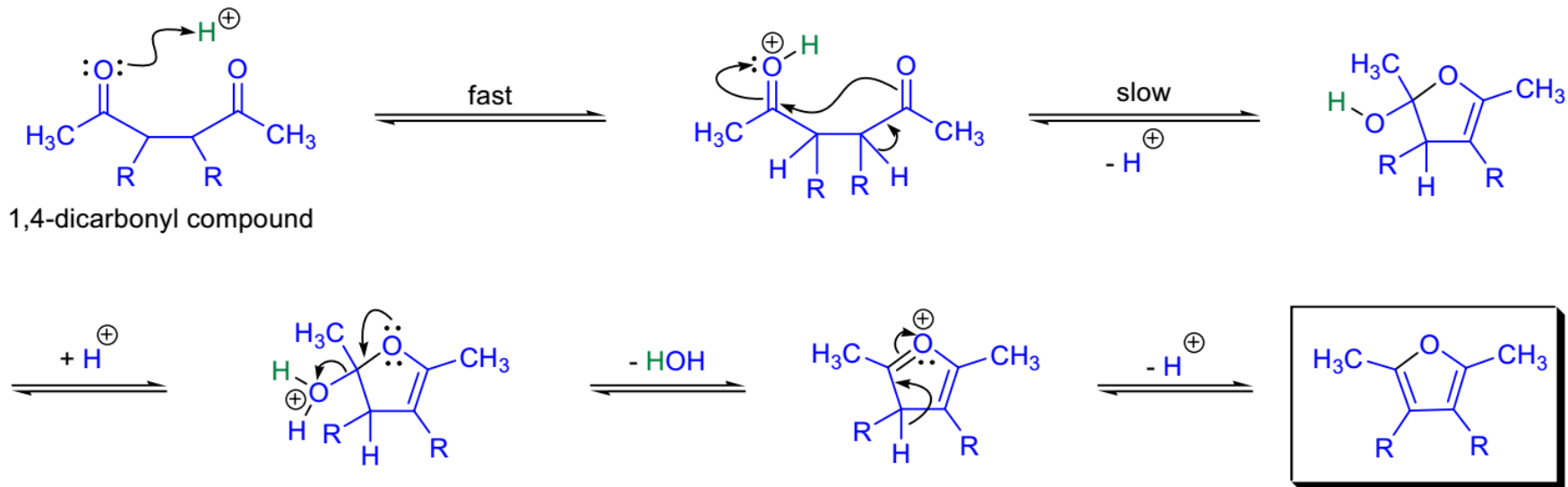


Synthetic Applications

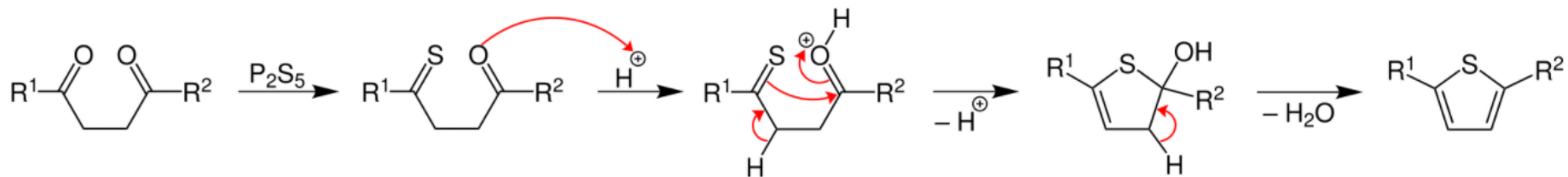


Related Reactions

Paal-Knorr Furan Synthesis

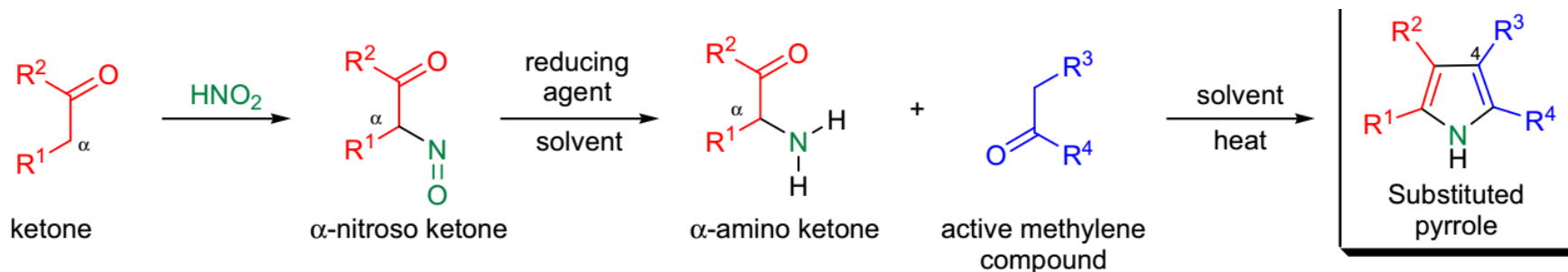


Thiophene synthesis

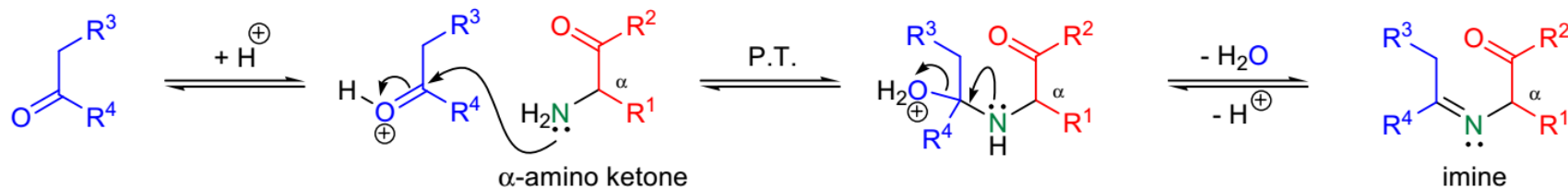


Related Reactions

Knorr pyrrole synthesis



Condensation of the amino ketone and ketone to give an imine:



Tautomerization of the imine to the enamine and cyclization:

