Bioassay. The specific-pathogen-free (SPF) fertile chicken eggs, used for the chick embryo bioassay,[14,15] were purchased from Larson Lab-Vac Eggs, Inc., Gowrie, IA 50543. The incubators used were the Imperial II produced by Lab-Line Instruments, Inc. and Model 3212-10 produced by National Appliance Company. The temperature was maintained at 37 °C and the relative humidity was kept at ca. 60%. Embryos were received within 24 h of laying, incubated for 5 days, and candled for viability. Typically a batch of 150 eggs would yield 120 acceptable eggs. Before dosing, the air cells were circled with a pencil and swabbed with 200 proof EtOH (Midwest Solvents Company of Illinois). An 18-gauge needle, sterilized in 200 proof ethanol, was used to puncture the shell above the encircled air cell. The toxins were dissolved in 200 proof EtOH, serial diluted, and 10 μL injected into the air cell with a microsyringe. The hole was then sealed with Scotch tape; 10 μL of 200 proof EtOH was injected into the control eggs. In 4 days the eggs were candled and the number of dead embryos were determined for each dose level.

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Reaction of Cyclopropenones with Trimethylsilyl Cyanide with the Aid of Transition-Metal Complexes or Phosphines.[1] A New Synthesis of 5-Amino-2-furancarbonitriles

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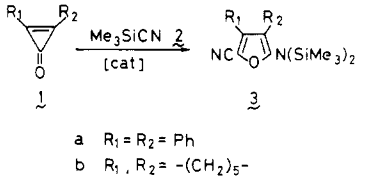
Diphenylcyclopropenone (**1a**) was first synthesized in 1959 by Breslow et al.[2] and Vol'pin et al.[3] Since that time there have been reported many reactions[4] involving cycloaddition[5] and nucleophilic addition. The interaction between cyclopropenones and transition-metal complexes has also been of interest.[6] We have now found that transition-metal complexes and phosphines are effective catalysts for the reaction of trimethylsilyl cyanide, Me_3SiCN (**2**), with cyclopropenones to give 5-amino-2-furancarbonitriles (eq 1).

Table I. Reaction of Diphenylcyclopropenone (1a) with Trimethylsilyl Cyanide (2)[a]

entry	catalyst	temp, °C	yield,[b] %
1	$Fe_2(CO)_9$	reflux[c]	41
2	$Ni(PPh_3)_2(CO)_2$	reflux	48
3	$Rh(PPh_3)_3Cl$	reflux	62
4	$Pt(PPh_3)_2Cl_2$	reflux	56
5	$Ir(PPh_3)_2(CO)Cl$	reflux	61
6	PPh_3	reflux	52
7	PPh_3	60	55
8	PPh_3	25	4
9	$P(4\text{-}MeOC_6H_4)_3$	60	55
10	$P(4\text{-}MeC_6H_4)_3$	60	46
11	PBu_3	60	14
12	$Ph_2CH_2CH_2PPh_2$	60	24

[a] Reaction conditions: diphenylcyclopropenone (0.8 mmol, 165 mg), Me_3SiCN (4.8 mmol, 0.65 mL), catalyst (0.032 mmol, 4 mol %). [b] Isolated yields based on **1a**. [c] Reflux temperature of reaction mixture; bp (Me_3SiCN) 115 °C.



(1)

The reaction of diphenylcyclopropenone (**1a**) with **2** in the presence of $Fe_2(CO)_9$ under reflux gave 5-[*N*,*N*-bis(trimethylsilyl)amino]-3,4-diphenyl-2-furancarbonitrile (**3a**)[7] in 41% yield (entry 1 in Table I). $Co_2(CO)_8$, $CpCo(CO)_2$, $Rh_6(CO)_{16}$, $Ru_3(CO)_{12}$, and $[RhCl(CO)_2]_2$ showed little or no catalytic activity. On the other hand, transition metal–phosphine complexes were effective for the present reaction (entries 2–5).

Interestingly, phosphines alone were found to catalyze the present reaction.[8] Triphenylphosphine was effective enough to produce the furan **3a** in 55% yield even at 60 °C, at which temperature transition-metal complexes, e.g., $Fe_2(CO)_9$ and $Rh(PPh_3)_3Cl$, showed little catalytic activity (entry 7). Triphenylphosphine, tris(4-methylphenyl)phosphine, and tris(4-methoxyphenyl)phosphine all were effective catalysts. Tris(2-methylphenyl)phosphine, trimethyl phosphite, triphenylarsine, diphenyl sulfide, pyridine, and triethylamine did not show catalytic activity. PPh_3-catalyzed reaction of cycloheptenocyclopropenone

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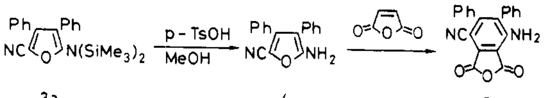
(**1b**) with **2** afforded 5-amino-2-furancarbonitrile **3b** in 55% yield.

Some attempts to prepare 5-amino-2-thiophenecarbonitriles have been unsuccessful so far. Thus, $Fe_2(CO)_9$- and PPh_3-catalyzed reactions of diphenylcyclopropenethione with **2** gave complex mixtures, and products containing a thiophene ring could not be isolated.

Desilylprotonation of **3a** leading to 5-amino-3,4-diphenyl-2-furancarbonitrile (**4**) took place upon treatment of **3a** with refluxing methanol containing a catalytic amount of *p*-toluenesulfonic acid (*p*-TsOH). Treatment of the furan **4** with maleic anhydride in refluxing dioxane gave the Diels–Alder[9] adduct, which lost water spontaneously affording the persubstituted phthalic anhydride **5** (eq 2).



3a 4 5 (2)

In summary, the present reaction provides a new, simple method for construction of a furan ring. Furan derivatives reported above are highly functionalized and would be useful both for further elaboration and for use as Diels–Alder dienes.

Experimental Section

Melting points were uncorrected. ^1H NMR spectra were recorded on a Bruker WM 360 and are reported in ppm from tetramethylsilane as the internal standard on the δ scale. Data are reported as follows: chemical shift, multiplicity (s = singlet, quint = quintet, m = multiplet, c = complex), coupling constant (hertz), integration, and interpretation. ^{13}C NMR were recorded on a Brucker WM 360 and are reported in ppm from tetramethylsilane. Infrared spectra were obtained on a Hitachi 260-10 spectrometer. Mass spectra were obtained on a JMS-DX 300. Elemental analyses were performed on a Perkin-Elmer 240C. Preparative TLC was performed with Merck Kieselgel 60 F_{254} with mixtures of hexane/EtOAc as an eluent.

Materials. Diphenylcyclopropenone,[2,10] diphenycyclopropenethione,[11] and cycloheptenocyclopropenone[12] were prepared by the methods reported in the literature. Transition-metal complexes were commercially obtained from Strem Chemicals, Inc., and were used without further purification. PPh_3 was recrystalized from hexane. Me_3SiCN was distilled from CaH_2 and stored under N_2.

5-[*N*,*N*-Bis(trimethylsilyl)amino]-3,4-diphenyl-2-furancarbonitrile (3a). To a 10-mL reaction flask were added diphenylcyclopropenone (165 mg, 0.8 mmol), PPh_3 (7 mg, 0.032 mmol), and Me_3SiCN (0.65 mL, 4.8 mmol). The mixture was stirred under N_2 at 60 °C for 20 h. Evaporation of excess Me_3SiCN followed by preparative TLC (silica gel, hexane/EtOAc = 85/15) gave 179 mg of **3a**: 55% yield; mp 96–97 °C (hexane); ^1H NMR ($CDCl_3$) δ 0.07 (s, 18 H, $SiCH_3$), 7.11–7.14 (m, 2 H, Ph), 7.26–7.33 (c, 8 H, Ph); ^{13}C NMR ($CDCl_3$) δ −1.41, 111.7, 113.0, 114.7, 125.9, 127.0, 127.1, 127.2, 127.4, 128.3, 128.6, 130.0, 137.6, 156.2; IR (Nujol) 2220 (CN), 1610, 1595, 1570 cm^{-1}; mass spectrum, *m/e* 404 (M^+). Anal. Calcd for $C_{23}H_{28}N_2OSi_2$: C, 68.27; H, 6.97; N, 6.92. Found: C, 68.15; H, 6.84; N, 6.80.

3-[*N*,*N*-Bis(trimethylsilyl)amino]-2,4,5,6,7,8-hexahydrocyclohepta[*c*]furan-1-carbonitrile (3b). To a 10-mL reaction flask were added cycloheptenocyclopropenone (98 mg, 0.8 mmol), PPh_3 (7 mg, 0.032 mmol), and Me_3SiCN (0.65 mL, 4.8 mmol). The mixture was stirred under N_2 at 60 °C for 20 h. Evaporation of excess Me_3SiCN followed by preparative TLC (silica gel, hexane/EtOAc = 90/10) gave 141 mg of the aminofurancarbonitrile **3b**: 55% yield; ^1H NMR ($CDCl_3$) δ 0.10 (s, 18 H, $SiCH_3$), 1.56 (quint, J = 5.1 Hz, 2 H, CH_2), 1.65 (quint, J = 5.1 Hz, 2 H, CH_2), 1.79 (quint, J = 5.1 Hz, 2 H, CH_2), 2.34 (m, 2 H, $=CCH_2$), 2.61 (m, 2 H, $=CCH_2$); ^{13}C NMR ($CDCl_3$) δ −1.41, 24.46, 25.69, 27.27, 27.40, 30.99, 111.5, 113.8, 115.7, 141.2, 153.6; IR (neat) 2960, 2930, 2850, 2220 (CN), 1620, 1550, 1455, 1425, 1270, 1255, 910, 930, 880, 865, 825, 760 cm^{-1}; mass spectrum, *m/e* 320 (M^+). Anal. Calcd for $C_{16}H_{28}N_2O_1Si_2$: C, 59.95; H, 8.80; N, 8.74. Found: C, 58.43; H, 8.87; N, 8.76.

7-Amino-1,3-dihydro-1,3-dioxo-5,6-diphenyl-4-isobenzofurancarbonitrile (5). A mixture of **3a** (410 mg, 1.0 mmol) and *p*-TsOH (40 mg, 0.21 mmol) was refluxed in CH_3OH (10 mL). After 3 h, the solution was cooled to room temperature and then diluted with $CHCl_3$ (200 mL) and cold water (100 mL). The organic phase was separated, and the aqueous phase was extracted with $CHCl_3$ (50 mL × 2). The combined organic phases were washed with water (50 mL × 2) and dried over $MgSO_4$. The solvent was evaporated in vacuo to give a crude 4 (249 mg, 97% yield), which is used without purification. A solution of the furan 4 and maleic anhydride (294 mg, 3.0 mmol) in dioxane (5 mL) was heated under reflux overnight with stirring. After the solution was cooled to room temperature, a yellow precipitate was collected, washed with dioxane and hexane, and dried to give a pure **5**: 179 mg, 53% yield; mp 285–286 °C (dioxane); IR (Nujol) 3460 (NH), 3310 (NH), 2240 (CN), 1850, 1765 (C=O), 1615 cm^{-1}; mass spectrum, *m/e* 340 (M^+). Anal. Calcd for $C_{21}H_{12}N_2O_3$: H, 74.11; H, 3.55; N, 8.23. Found: C, 74.66; H, 3.21; N, 8.33.

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