2-Allylisourea as a Starting Material for Palladium-Catalyzed Wittig-Type Allylidenation of Aldehydes

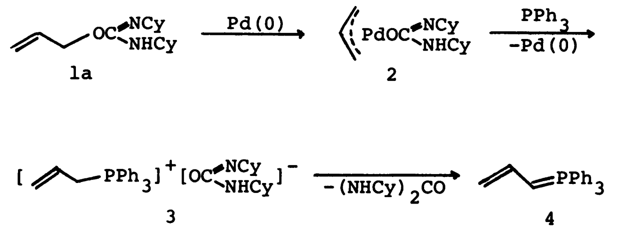
Yoshio Inoue,* Masanori Toyofuku, and Harukichi Hashimoto
Department of Applied Chemistry, Faculty of Engineering, Tohoku University, Aoba, Aramaki, Sendai 980

(Received November 21, 1985)

Synopsis. 2-Allylic-substituted isoureas underwent Wittig-type allylidenation of aldehydes in the presence of triphenylphosphine and 2 mol% of [Pd(PPh$_3$)$_3$] to give the corresponding conjugated olefins in tolerable to good yields.

π-Allylpalladium chloride complex reacts with several nucleophiles such as stabilized carbanions (pK_a 10—20), enamines, and amines.[1a)] The reaction is a well-established and useful synthetic method.[1b)] Phosphines are also good nucleophiles, and an excess of triphenylphosphine has actually been shown to react with π-allylpalladium chloride in aqueous acetone to give [Pd(PPh$_3$)$_4$] and an allylic phosphonium salt.[2a)] However this finding has not been fully utilized in organic syntheses.[2b,c)] For example, the reaction of several aldehydes with allylic alcohols and triphenylphosphine under palladium catalysis has been reported.[2b)]

Previously we reported that 2-allyl-1,3-dicyclohexylisourea (**1a**) was an efficient allylating agent for ketones,[3a)] imides,[3b)] and amides[3c)] in the presence of a palladium (0) complex. The suggested reaction pathway involves the π-allyl intermediate **2** which is formed by the oxidative addition of **1a** to a palladium (0) complex. If triphenylphosphine reacts with **2** as a nucleophile, the phosphonium salt **3** may be formed. The isourea anion in **3** is a strong base and is expected to abstract an α-proton to afford allylidenetriphenylphosphorane (**4**). On this consideration we attempted Wittig-type allylidenation of aldehydes catalyzed by palladium (0) employing 2-allylisourea **1a** as the starting material.



A DMF solution of **1a** (1.0 equiv), triphenylphosphine (1.0 equiv), and benzaldehyde (1.0 equiv) was stirred at 50 °C for 3 h in the presence of 2 mol% of [Pd(PPh$_3$)$_3$]. 1-Phenyl-1,3-butadiene (**5a**) was obtained in 86% yield (E:Z=33:67) after chromatographic work-up. Ketones such as acetone, acetophenone, and benzophenone did not participate in the reaction. Tributylphosphine gave significantly lower yields of the products. Benzene could be used as a solvent in place of DMF without altering appreciably the product composition. Various conjugated olefins could be prepared from aldehydes and allylic-substituted isoureas **1** in tolerable to good yields. The results are shown in Table 1. Employment of an excess **1** increased the yields of the products. Linear dienes were obtained predominantly even though starting from an α-branched isourea, i.e., 2-(1-methyl-2-propenyl)isourea **1b′**. The same mixture as above was also obtained starting from 2-(2-butenyl)isourea **1b** indicating that the intermediate for each should be

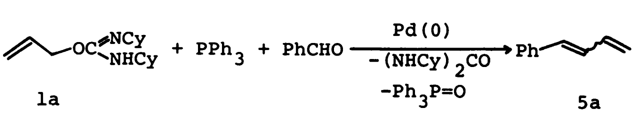
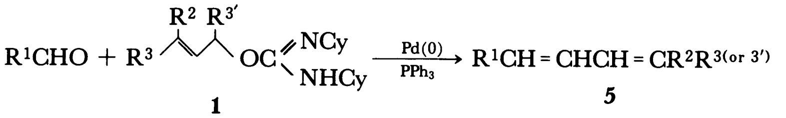


Table 1. Olefinization of Aldehydes with Allylic-Substituted Isoureas 1[a)]



$$R^1CHO + R^3CH{=}CR^2CHR^{3'}OC(=NCy)NHCy \xrightarrow[PPh_3]{Pd(0)} R^1CH{=}CHCH{=}CR^2R^{3(or\ 3')}$$

1 **5**

Aldehyde R^1		Isourea 1			Reaction temp /time	Yield **5**[b)]	Composition[c)]
		R^2,	R^3,	R$^{3'}$	°C/h	%	%
Ph	**1a**	H,	H,	H	50/3	**5a** 86 (98)[d)]	Z:E=67:33
	1b	H,	CH$_3$,	H	80/3	**5b** 47 (68)[d)]	1Z,3E:1E,3E=52:32[e)]
	1b′	H,	H,	CH$_3$	80/3	**5b** (69)[d)]	1Z,3E:1E,3E=54:30[e)]
	1c	H,	C$_3$H$_7$,	H	80/3	**5c** 40 (94)[d)]	1Z,3E:1E,3E=61:30[f)]
	1d	H,	Ph,	H	80/3	**5d** 94	1Z,3E:1E,3E=64:36
	1e	CH$_3$,	CH$_3$,	H	80/3	**5e** 47	Z:E=69:31
	1f	CH$_3$,	C$_6$H$_{11}$, (geranyl)	H	80/3	**5f** 48	1Z,3E:1E,3E=75:25
C$_3$H$_7$	**1d**	H,	Ph,	H	68/3	**5c** 38	1E,3Z: 1E,3E=51:49

a) Reaction conditions; see experimental part. b) Isolated yield. c) Area ratio of the GLC peaks. d) Excess isourea **1** (2.0 equiv) was used. e) In addition, 1Z,3Z-isomer (12%) and 2-methyl-1-phenyl-1,3-butadiene (4%) were formed. f) 1Z,3Z- and 1E,3Z-isomers were also obtained in 6 and 3%, respectively.

same and that triphenylphosphine attacked preferencially the less hindered end of the π-allylic group. The initial *E*-geometry in the isoureas was almost preserved during the course of the reaction, but the stereoselectivity about a newly-formed double bond was not observed.[4]

The present reaction generally provides higher yields of dienes 5 under milder reaction conditions compared to the similar palladium-catalyzed Wittig-type olefinization involving allylic alcohols.[2b] It should be noted that this reaction proceeds under neutal conditions in contrast to the normal Wittig reaction in which basic conditions are adopted for the generation of phosphoranes from phosphonium salts.

Experimental

Materials. Allylic-substituted isoureas **1** were prepared from allylic alcohols and dicyclohexylcarbodiimide in the presence of a catalytic amount of copper(I) chloride according to the reported method.[5] $[Pd(PPh_3)_3]$ was synthesized according to the known procedure.[6]

General Procedure for the Olefinization of Aldehydes with 1 (Table 1). A DMF solution (5 cm^3) of an allylic-substituted isourea **1** (2 mmol), triphenylphosphine (524 mg, 2 mmol), and an aldehyde (2 mmol) was stirred at 80 °C under nitrogen in the presence of $[Pd(PPh_3)_3]$ (36 mg, 0.04 mmol). After 3 h, the reaction mixture was diluted with diethyl ether and the *N,N'*-dicyclohexylurea formed was filtered off. The filtrate was washed with saturated NaCl solution. The organic layer was dried over $MgSO_4$ and concentrated. The products were isolated by column chromatography on silica gel eluting with hexane. The isomer ratio was determined by GLC (Silicone GE SE-52, 20%, 2 m, for **5a—c**, **5e**, **5f**, or OV-1, 3%, 2 m, for **5d**). Individual isomer was separated by GLC (for **5a—c**, **5e**, **5f**) or TLC (for **5d**; silica gel, hexane/ethyl acetate=20/1).

1-Phenyl-1,3-butadiene (5a): *Z*-Isomer; ^1H NMR ($CDCl_3$) δ=5.05—5.49 (m, 2H), 6.00—7.02 (m, 3H), 7.28 (s, 5H). IR (neat) 1000, 900, 805, 770 cm^{-1}. *E*-isomer; ^1H NMR ($CDCl_3$) δ=4.98—5.54 (m, 2H), 6.15—7.18 (m, 3H), 7.18—7.46 (m, 5H). IR (neat) 1630, 1600, 1000, 950, 900 cm^{-1}.

1-Phenyl-1,3-pentadiene (5b): 1*Z*,3*E*-Isomer; ^1H NMR ($CDCl_3$) δ=1.80 (d, 3H), 5.96 (dq, 1H), 6.00—6.88 (m, 3H), 7.28 (s, 5H). IR (CCl_4) 1640, 1600, 985, 950, 930 cm^{-1}. 1*E*,3*E*-isomer; ^1H NMR δ=1.84 (d, 3H), 5.92 (dq, 1H), 6.00—6.86 (m, 3H), 7.04—7.58 (m, 5H). IR ($CDCl_3$) 1595, 1445, 980 cm^{-1}.

1-Phenyl-1,3-heptadiene (5c): 1*Z*,3*E*-Isomer; ^1H NMR ($CDCl_3$) δ=0.97 (t, 3H), 1.11—1.76 (m, 2H), 2.10 (q, 2H), 5.82 (dt, 1H), 5.88—6.10 (m, 3H), 7.08—7.54 (m, 5H). IR (neat) 1650, 1600, 1405, 980 cm^{-1}. 1*E*,3*E*-isomer; ^1H NMR ($CDCl_3$) δ=0.94 (t, 3H), 1.14—1.75 (m, 2H), 2.13 (q, 2H), 5.78 (dt, 1H), 6.02—6.99 (m, 3H), 7.06—7.52 (m, 5H). IR (neat) 1645, 1600, 990 cm^{-1}.

1,4-Diphenyl-1,3-butadiene (5d): The structures of the isomers (1*Z*,3*E*- and 1*E*,3*E*-) were determined by ^1H NMR and IR spectra comparing with the reported ones.[2c]

4-Methyl-1-phenyl-1,3-pentadiene (5e): *Z*-Isomer; ^1H NMR ($CDCl_3$) δ=1.82 (s, 6H), 6.36 (s, 3H), 7.03—7.41 (m, 5H). IR (neat) 1645, 1595, 790, 725 cm^{-1}. *E*-isomer; ^1H NMR ($CDCl_3$) δ=1.85 (s, 6H), 5.82—7.05 (m, 3H), 7.08—7.58 (m, 5H). IR (neat) 1645, 1595, 955 cm^{-1}.

4,8-Dimethyl-1-phenyl-1,3,7-nonatriene (5f): 1*Z*,3*E*-Isomer; ^1H NMR ($CDCl_3$) δ=1.60 (s, 3H), 1.69 (s, 3H), 1.82 (s, 3H), 2.12 (m, 4H), 5.09 (br, 1H), 6.35 (s, 3H), 7.08—7.50 (m, 5H). IR (neat) 1640, 1600, 795, 725 cm^{-1}. 1*E*,3*E*-isomer; ^1H NMR ($CDCl_3$) δ=1.62 (s, 3H), 1.69 (s, 3H), 1.89 (s, 3H), 2.15 (m, 4H), 5.13 (br, 1H), 5.95—7.07 (m, 3H), 7.10—7.59 (m, 5H). IR (neat) 1640, 1600, 965 cm^{-1}.

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