Practical Synthesis of (*E*)-Pent-3-en-2-one and Its Conversion to (*E*)-2-Triethylsilyloxypenta-1,3-diene

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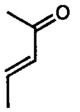
An improved procedure for the preparation of (*E*)-pent-3-en-2-one in high yields utilizing a Friedel–Crafts type alkylation of crotonyl chloride with trimethylaluminum is reported. Conversion of this enone into the corresponding enol silyl ether is also described.

As a part of our program on the synthesis of dynemicin A through Diels–Alder reaction of a 2-quinolone derivative with silyloxydiene, a large quantity of (*E*)-pent-3-en-2-one (**1**) was required for the preparation of the corresponding enol silyl ether such as **2**.[1] Although compound **1** is commercially available, the purity (~ 60 %) was not enough for our purpose. Two reliable methods are reported for the large scale preparation of **1**. House has recommended the Wittig reaction between acetaldehyde and the requisite ylide from 2-oxopropyltriphenylphosphonium chloride,[2] which avoids the tedious separation process of the previously reported procedure. Another protocol in Organic Synthesis[3] requires a hazardous gaseous reagent and thus special precautions.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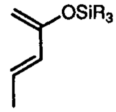
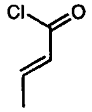


2a: R=Me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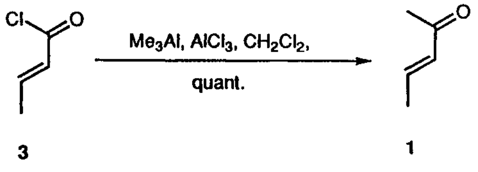
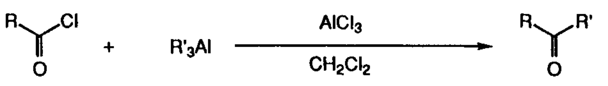
The obvious inconvenience of the latter method made us follow the House protocol. Although this procedure, in our hands, did produce good results, we found it inconvenient on a multigram scale operation. We therefore investigated a more convenient method which utilizes crotonyl chloride (**3**) as starting material. Attempted reaction of **3** with Grignard reagents (methylmagnesium bromide or methylmagnesium iodide) gave only equivocal results. On the other hand, the reaction of **3** with trimethylaluminum in the presence of a palladium catalyst according to Oshima protocol[4] gave **1** in less than 15 % yield. (Scheme 1) To avoid using the expensive palladium catalyst, we next examined the reaction of **3** with trimethylaluminum in the presence of aluminum chloride. Closely related reactions are reported by Russian chemists,[5] but they failed to describe the reaction of **3** and aluminum chloride. A gratifying success was realized when trimethylaluminum was added to a suspension of **3** and aluminum chloride under cooling. After stirring at room temperature, the mixture was worked up as usual, affording **1** in nearly quantitative yield by distillation.



Scheme 1

Encouraged by this result, we next tested the same reaction with other substrates for the purpose of investigating the usefulness of this method. Results are summarized in the Table. It should be noticed here that these reactions were not described by previous authors,[5] thus we present here useful information about its scope and limitation.

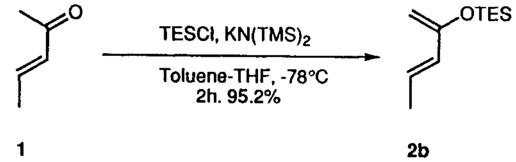


With enough quantity of **1** in hand, we then returned to our immediate synthetic objective, an efficient conversion of **1** to the required siloxydiene **2** (Scheme 2). By proper choice of the base potassium bis(trimethylsilyl)amide and the solvent system (toluene/THF), we obtained the novel triethylsilyloxydiene **2** in satisfactory yield, which shows a greater stability than the known trimethylsilyloxydiene. The detailed Diels–Alder reaction of these dienes will be reported elsewhere.

Table. Reaction of Trialkylaluminum with Acid Chlorides

Acid chloride	R'_3Al	Product	Yield (%)	bp (°C)/Torr	
				found	reported
MeCH=CHCOCl	Me_3Al	MeCH=CHCOMe (**1**)	~ 100	40/30	121.5–124/760[3]
Me_2C=CHCOCl	Me_3Al	Me_2C=CHCOMe (**4**)	73	40/30	126–130/760[6]
PhCH=CHCOCl	Me_3Al	PhCH=CHCOMe (**5**)	95	mp 39–41	mp 40–42[7]
PhCOCl	Me_3Al	PhCOMe (**6**)	93	90/20	202/760[8]
$PhCH_2CH_2COCl$	Me_3Al	$PhCH_2CH_2COMe$ (**7**)	91	–[a]	63/0.7[9]
$PhCH_2COCl$	Me_3Al	$PhCH_2COMe$ (**8**)	75	140/20	105–106/20[10]
$C_7H_{15}COCl$	Me_3Al	$C_7H_{15}COMe$ (**9**)	98	–[a]	106/12[11]
MeCH=CHCOCl	Et_3Al	MeCH=CHCOEt (**10**)	96	50/25	137/760[12]

[a] Purified by silca gel column chromatography and identified by ^1H NMR, ^{13}C NMR and mass spectroscopy.



Scheme 2

In summary, we have established a convenient one-step preparation of **1**, which avoids the multistep of the previous reports. Furthermore, **1** was easily transformed to the relatively stable diene **2**, which will be employed as a useful diene partner in the synthesis of dynemicin A and others. In view of the scope and the limitation, additional data for this Friedel–Crafts type alkylation reaction was obtained (Table). Utilization of this simple protocol to some natural product synthesis will be reported in due course.

(*E*)-Pent-3-en-2-one (1); Typical Procedures.

Pd-Catalysed Preparation: Me_3Al (1.05 M hexane solution, 59.6 mL, 62.6 mmol) was added to a THF (40 mL) solution of crotonyl chloride (3.27 g, 31.3 mmol) and $Pd(PPh_3)_4$ (1.81 g, 1.56 mmol) at 0 °C under an Ar atmosphere. The mixture was stirred at 25 °C for 4.5 h, poured into 1 M HCl and extracted with Et_2O. The combined organic layers were dried (Na_2SO_4) and concentrated in vacuo. Purification by distillation gave (*E*)-pent-3-en-2-one (**1**) as a colorless oil; yield: 0.33 g (13 %).

$AlCl_3$-Promoted Preparation: To a cooled (– 50 °C) suspension of $AlCl_3$ (4.17 g, 31.3 mmol) in CH_2Cl_2 (25 mL), was added a solution of the crotonyl chloride (3.27 g, 31.3 mmol) in CH_2Cl_2 (10 mL) over 15 min under an Ar atmosphere. The mixture was stirred for about 1 h, cooled to – 30 °C, and a solution of a Me_3Al (12.0 mL, 12.5 mmol) in CH_2Cl_2 (12 mL) was added over 30–60 min. The mixture was then kept at r. t. for 2 h, recooled to 0 °C, and quenched by the addition of water. The organic layer was separated and the aqueous layer was washed with Et_2O. The combined organic layers were washed with 5 % aq $NaHCO_3$, solution of water, and dried (Na_2SO_4). After removal of the solvent, the residue was subjected to distillation under reduced pressure, affording **1** as a colorless oil; yield: 2.63 g (~ 100 %); bp 40 °C/30 Torr.

(*E*)-2-(Triethylsilyloxy)penta-1,3-diene (2b):

To a cooled (– 78 °C) and stirred solution of **1** (2.12 g, 25.2 mmol) in toluene (40 mL)/THF (20 mL), was added chlorotriethylsilane (5.69 g, 37.8 mmol) under an Ar atmosphere. After stirring for 5 min, $KN(SiMe_3)_2$ (7.54 g, 37.8 mmol) was added as a powder. The mixture was kept stirring at – 78 °C for 2 h, and quenched by the addition of water. The organic layer was separated and the aqueous layer was extracted with hexane. The combined organic layers were dried (Na_2SO_4), and concentrated in vacuo. Purification by distillation under reduced pressure gave **2** as a colorless oil.

IR (neat): ν = 2970, 2920, 2890, 2660, 1595, 1460, 1415, 1380, 1325, 1300, 1255, 1245, 1070, 1020, 965, 900, 840, 805, 740 cm^{-1}.

^1HNMR ($CHCl_3$): δ = 0.72 (6 H, q, J = 9.3 Hz, $C\underline{H}_2CH_3$), 0.99 (9 H, t, J = 9.3 Hz, $CH_2C\underline{H}_3$), 1.76 (3 H, d, J = 6.7 Hz, CH_3), 4.17 (1 H, s, $=CH_2$), 4.20 (1 H, s, $=CH_2$), 5.89 (1 H, d, J = 16.3 Hz, $CH_3CH=C\underline{H}$), 6.17 (1 H, m, $CH_3C\underline{H}=CH$).

^{13}CNMR ($CHCl_3$): δ = 4.96, 6.81, 17.56, 93.02, 126.33, 129.08, 155.09.

HRMS (FAB): m/z Calc. for $C_{11}H_{23}OSi$ (MH^+) 199.1518; found 199.1522.

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