2′,5′-di-O-acyl nucleoside into the 3′,5′ isomer upon chromatography[8] or to preferred crystallization of the 3′,5′-di-O-acyl nucleoside from an equilibrating mixture of isomers in solution, as suggested by observations of acyl migration in such systems,[9] is not clear. Nevertheless, 3′,5′-di-O-acyl derivatives are generally isolable in 60–75% yields from the fully acylated nucleosides.

3′,5′-Di-O-benzoyl ribonucleosides 1 obtained in this manner from fully benzoylated nucleosides were thiobenzoylated under the mildest conditions possible so as to minimize further acyl migration[9] before reaction (Scheme I). Treatment of the 3′,5′-di-O-benzoyl ribonucleoside with the chloroiminium chloride derived from N,N-dimethylbenzamide and phosgene, followed by hydrogen sulfide/pyridine,[7] gave the 3′,5′-di-O-benzoyl-2′-O-thiobenzoyl ribonucleosides 2 in 75–80% yields. Reductive cleavage of these thiobenzoates with tributylstannane in refluxing toluene under conditions of inverse addition afforded the 2′-deoxy-3′,5′-di-O-benzoyl nucleosides 3 in 85–90% yields. The absence of detectable amounts of the 3′-deoxy-2′,5′-di-O-benzoyl nucleosides in the reaction mixtures indicates that acyl migration is sufficiently slow to allow derivatization of the 2′-hydroxyl of 1 exclusively. Examples are provided in the Experimental Section for the conversion of 3′,5′-di-O-benzoyladenosine (**1a**) to 2′-deoxy-3′,5′-di-O-benzoyladenosine (**3a**) in 73% overall yield and of N^2,3′-O,5′-O-tribenzoylguanosine (**1b**) to 2′-deoxy-N^2,3′-O,5′-O-tribenzoylguanosine (**3b**) in 66% overall yield. Final ammonolysis to the deoxyribonucleosides 4 is amply documented. The general composite method outlined in Scheme I is particularly applicable to the synthesis of derivatives and analogues of the naturally occurring 2′-deoxyribonucleosides when fully acylated precursors are available.

Experimental Section

3′,5′-Di-O-benzoyl ribonucleosides 1 were prepared as previously described.[8] Melting points were determined with a Büchi capillary melting point apparatus and are uncorrected. ^{1}H NMR spectra were recorded on a Varian EM-390 spectrometer using Me_4Si as an internal standard. Reactions were monitored by TLC on Merck f-254 precoated silica gel plates with 15% methanol in chloroform as the developing solvent. Column chromatography was performed on Brinkman 0.05–0.2-mm silica gel. High-resolution mass spectra were obtained on a Varian MAT 731 spectrometer, coupled with a 620i computer and a STATOS recorder.

3′,5′-Di-O-benzoyl-2′-O-thiobenzoyladenosine (2a). A solution of N,N-dimethylbenzamide (0.8 g, 5.4 mmol) in dry dichloromethane (20 mL) was treated with condensed phosgene (4 mL), the solution was stirred overnight, and the solvent and excess phosgene were removed in vacuo. The residue was dissolved in dry dichloromethane (20 mL), and 3′,5′-di-O-benzoyladenosine (**1a**; 0.11 g, 0.23 mmol) was added as a solid. The mixture was stirred for 12 h, pyridine (3 mL) was added, and hydrogen sulfide was bubbled through the mixture for 10 min. The resulting solution was washed with water (2 × 20 mL), 2 N sulfuric acid (2 × 20 mL), and saturated aqueous sodium bicarbonate, dried over sodium sulfate, and evaporated in vacuo. The residue was dissolved in chloroform and chromatographed on silica gel. Elution with chloroform gave N,N-dimethylthiobenzamide. Further elution with 2% methanol in chloroform gave **2a** as a yellow glass: 110 mg (82%); ^{1}H NMR ($CDCl_3$, D_2O added) δ 4.93 (m, 3 H, H-4′,5′,5″), 6.56 (m, 1 H, H-3′), 6.65 (d, 1 H, H-1′, $J_{1',2'}$ = 6 Hz), 6.93 (dd, 1 H, H-2′, $J_{1',2'}$ = 6 Hz, $J_{2',3'}$ = 6 Hz), 7.3–7.8 (br m, 10 H, 2 C_6H_5), 8.1–8.4 (br m, 6 H, H-8 and C_6H_5), 8.53 (s, 1 H, H-2); $C_{31}H_{25}N_5O_6S$.

2′-Deoxy-3′,5′-di-O-benzoyladenosine (3a). To a solution of 3′,5′-di-O-benzoyl-2′-O-thiobenzoyladenosine (**2a**; 132 mg, 0.22 mmol) in refluxing toluene (25 mL) was added a solution of tri-n-butyltin hydride (0.15 mL) in toluene (25 mL) dropwise over a period of 2 h. The mixture was heated at reflux for an additional 30 min and then was allowed to stand at room temperature for 12 h. Solvent was removed in vacuo, and the residue was dissolved in chloroform and chromatographed on silica gel. Elution with a 0–4% methanol gradient in chloroform afforded 2′-deoxy-3′,5′-di-O-benzoyladenosine (**3a**) as a glass (94 mg, 89%), identical with an authentic sample by TLC and NMR: ^{1}H NMR ($CDCl_3$) δ 2.87 (ddd, 1 H, H-2′, $J_{1',2'}$ = 8 Hz, $J_{2',3'}$ = 4 Hz, $J_{2',2''}$ = 14 Hz), 3.25 (dd, 1 H, H-2″, $J_{1',2''}$ = 9 Hz, $J_{2',2''}$ = 14 Hz), 4.85 (br m, 3 H, H-4′,5′,5″), 6.03 (br m, 1 H, H-3′), 6.23 (br s, 2 H, NH_2), 6.74 (dd, 1 H, H-1′), 7.5–7.9 (br m, 6 H, C_6H_5 and H-8), 8.1–8.5 (br m, 5 H, C_6H_5), 8.58 (s, 1 H, H-2); $C_{24}H_{21}N_5O_5$.

2′-O-(Thiobenzoyl)-N^2,3′-O,5′-O-tribenzoylguanosine (2b). A solution of N,N-dimethylbenzamide (1.4 g, 9.3 mmol) in dry dichloromethane (40 mL) was treated with condensed phosgene (4 mL) with stirring under nitrogen for 18 h. Solvent and excess phosgene were removed in vacuo, and the residue was dissolved in dry dichloromethane (20 mL). N^2,3′-O,5′-O-Tribenzoylguanosine (**1b**; 330 mg, 0.55 mmol) was added as a solid. The mixture was stirred for 24 h, pyridine (4 mL) was added, and hydrogen sulfide was bubbled through the mixture for 10 min. The mixture was stirred for an additional hour, washed with water (2 × 20 mL), 2 N sulfuric acid (2 × 20 mL), and saturated aqueous sodium bicarbonate (2 × 20 mL), dried over sodium sulfate, and evaporated in vacuo. The residue was dissolved in chloroform and chromatographed on silica gel. Elution with chloroform gave N,N-dimethylthiobenzamide. Further elution with 2% methanol in chloroform afforded 2′-O-(thiobenzoyl)-N^2,3′-O,5′-O-tribenzoylguanosine (**2b**) as a yellow glass: 306 mg (79%); ^{1}H NMR ($CDCl_3$) δ 5.0 (br m, 3 H, H-4′,5′,5″), 6.50 (m, 1 H, H-3′), 6.9–7.1 (br m, 2 H, H-1′,2′), 7.3–8.5 (br m, 21 H, $4C_6H_5$ and H-8), 10.1 (br s, 1 H, N^2H); high-resolution field-desorption mass spectrum calcd for $C_{38}H_{29}N_5O_6S$ m/e 715.1736, obsd 715.1731.

2′-Deoxy-N^2,3′-O-tribenzoylguanosine (3b). A solution of 2′-O-(thiobenzoyl)-N^2,3′-O,5′-O-tribenzoylguanosine (**2b**; 294 mg, 0.41 mmol) in toluene (40 mL) was heated to reflux. A solution of tri-n-butyltin hydride (0.15 g) in toluene (40 mL) was added dropwise over the period of 2 h with stirring under nitrogen. The reaction was cooled, and the solvent was removed in vacuo. The residue was dissolved in chloroform and chromatographed on silica gel. Elution with chloroform to remove nonpolar materials was followed by elution with 2% methanol in chloroform to give 2′-deoxy-N^2,3′-O,5′-O-tribenzoylguanosine (**3b**) as a glass, 201 mg (85%). The product crystallized from methanol: mp 125–127 °C; ^{1}H NMR ($CDCl_3$) δ 2.65 (ddd, 1 H, $J_{1',2'}$ = 7 Hz, $J_{2',2''}$ = 14 Hz, $J_{2',3'}$ = 3 Hz, H-2′), 3.18 (dd, 1 H, $J_{2'',3'}$ = 7 Hz, H-2″), 4.55 (br m, 2 H, H-4′,5′), 4.87 (dd, 1 H, $J_{5',5''}$ = 13 Hz, $J_{4',5''}$ = 8 Hz, H-5″), 5.77 (m, 1 H, H-3′), 6.15 (dd, 1 H, H-1′), 7.2–8.2 (br m, 16 H, $3C_6H_5$ and H-8); $C_{31}H_{25}N_5O_7 \cdot CH_3OH$ (C, H, N); high-resolution chemical-ionization mass spectrum calcd for $C_{31}H_{26}N_5O_7$ (M + H^+) m/e 580.1832, obsd 580.1826.

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Registry No. **1a**, 62374-24-7; **1b**, 62374-25-8; **2a**, 78763-65-2; **2b**, 78763-66-3; **3a**, 20838-22-6; **3b**, 78763-67-4; N,N-dimethylbenzamide, 611-74-5.

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Synthetic Applications of 2-Phenylselenenyl Enones. 2. Synthesis of Dihydrojasmone and *cis*-Jasmone

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2,3-Dialkylated cyclopentanones and cyclopentenones encompass a broad class of important, naturally occurring substances. Perhaps the best known and most often synthesized members of this class of compounds are two

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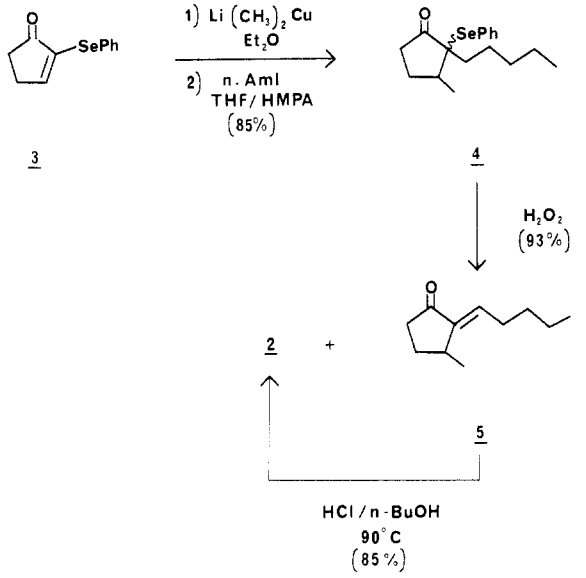
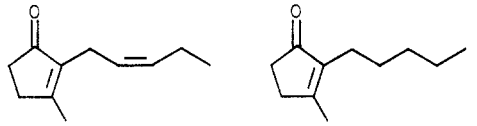
Scheme I



closely related substances, *cis*-jasmone (1) and dihydrojasmone (2).[2] Although these compounds continue to be



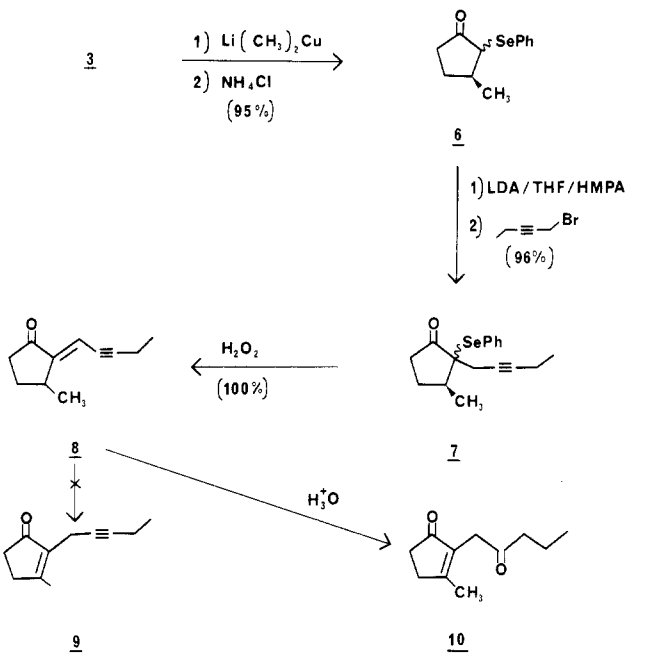
1 2

important raw materials in the perfume industry, the primary impetus for the numerous synthetic approaches to these substances centers around the development of new synthetic methodology aimed toward (a) the construction of five-membered rings or (b) the dialkylation of previously constructed cyclopentanones.

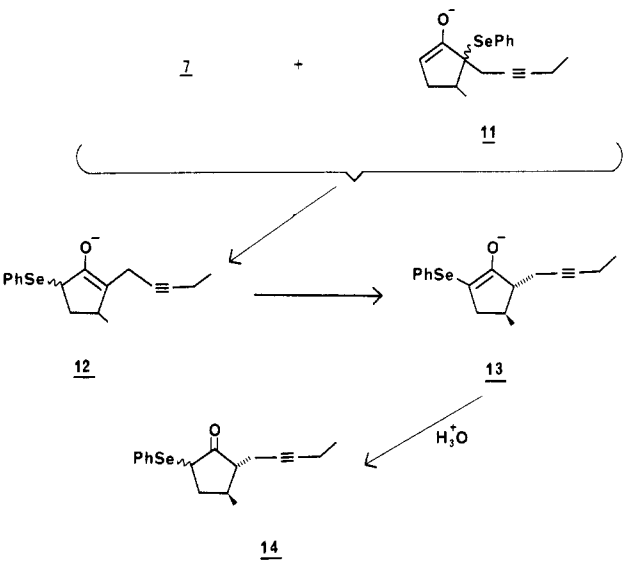
In this regard we have shown in a previous study that 2-phenylselenenyl enones undergo 2,3-dialkylations in high overall yields and that the resulting 2-phenylselenenyl ketones are versatile species which can be selectively converted into a number of different ketones and enones.[3] In this paper we report on the application of this methodology to the synthesis of 1 and 2.

Our approach to the synthesis of dihydrojasmone (2) is illustrated in Scheme I. Conjugate addition of lithium dimethylcuprate to 2-(phenylselenenyl)cyclopentenone (3)[4] in ether, followed by the subsequent addition of anhydrous THF, HMPA, and *n*-amyl iodide, results in the formation of an epimeric mixture of the 2,3-dialkyl-2-(phenylselenenyl) ketone 4 in 85% yield. Oxidative elimination of 4 in a two-phase system containing methylene chloride and 30% hydrogen peroxide solution leads to a mixture of two enones, 5 and 2, in 93% isolated yield. Isomerization of this mixture to 2 is accomplished in 85% yield by heating the mixture in HCl/*n*-BuOH at 90 °C.[3,5] Thus, the overall yield of 2 from 3 is 67% and, as such, represents one of the most efficient syntheses of dihydrojasmone yet reported.

Scheme II



Scheme III



Our synthesis of *cis*-jasmone (1) is shown in Schemes II and IV. All initial attempts to directly convert 3 to 7 by procedures analogous to those used in Scheme I yielded uniformly poor results (10–34% isolated yields). These poor results are unquestionably linked to the presence of some copper species,[6] since stepwise conversion of 3 of 6, and subsequent treatment of 6 with lithium diisopropylamide in THF/HMPA, followed by alkylation with pentynyl bromide, results in the formation of 7 in 96% overall yield. Oxidative elimination of 7 gives exclusively the pleasant smelling compound 8 (100% isolated yield). Interestingly, no trace of dehydrojasmone (9), a known precursor of 1, is observed.[7-9]

(1) Fellow of the Alfred P. Sloan Foundation, 1980–1984.

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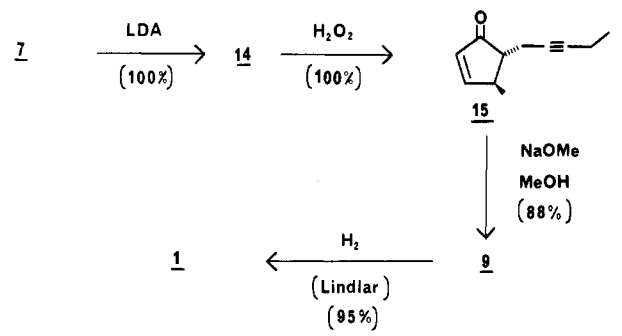
(6) The copper species apparently facilitates deselenation of a reaction intermediate or product, since the major product isolated in all these processes is pentynyl phenyl selenide.

(7) This unusual preference for exocyclic elimination (see ref 3) is undoubtedly due to stability derived from the extended conjugation in 8.

Scheme IV



Treatment of 8 with HCl/*n*-BuOH at 90 °C yields a complex mixture of products which apparently contains no **9**. Instead, it is composed of enedione **10** and a mixture of some uncharacterized chlorinated ketones. By using protic acids which are presumably less prone to do addition reactions (e.g., sulfuric acid or *p*-toluenesulfonic acid), we were able to dramatically improve the yield of **10**, but in no case could we isolate even trace amounts of **9**. Attempts to isomerize **8** to **9** using the "RhH" methodology, previously developed by Greico,[10] also failed in our hands.

Since all our attempts to isomerize **8** to **9** failed, we approached the problem in a different fashion (see Scheme III). We assumed that if **7** were treated with less than 1 equiv of base, the following sequence of events would occur. First, a mixture consisting of **7** and the corresponding enolate **11** should form. Upon warming, these species should undergo a series of exchange processes, first to produce **12** and then ultimately to form **13**. The driving force for each of these exchange reactions is the production of increasingly more stable enolate ions.

In practice, treatment of **7** with approximately 0.5 equiv of lithium diisopropylamide in THF/HMPA at −78 °C and subsequent quenching of the resulting enolate at room temperature with a saturated ammonium chloride solution results in the formation of **14** in quantitative yield[11,12] (see Scheme IV). Oxidative elimination of **14** in a two-phase system containing methylene chloride and 30% hydrogen peroxide solution produces **15** also in quantitative yield. Isomerization of **15** to **9** is achieved in 88% yield by using a modification of a procedure developed by Stork.[13]

Final conversion of **9** to **1** is accomplished according to literature procedures.[8,9] The overall yield for the conversion of **3** to **1** is 76%. To our knowledge the procedure described here represents the most efficient process yet reported for the synthesis of **1**. Application of this methodology to other 2,3-dialkylated ketones (e.g., prostaglandins) will be the subject of future reports.

Experimental Section

General Methods. Melting points were determined with a Thomas-Hoover Uni-Melt capillary melting point apparatus. Infrared spectra were determined with Perkin-Elmer Model 257, 457, and 727 spectrophotometers. Nuclear magnetic resonance spectra were recorded with Varian T-60, EM-360, and EM-390 spectrometers, and chemical shifts are reported in parts per million (δ) relative to an internal tetramethylsilane reference. Nominal mass spectra were recorded with a Finnigan 4000 GC/MS system and a Varian Associates M-66 spectrometer. Precise mass measurements were carried out with the Varian Associates M-66 spectrometer. Reagents and solvents were purified by standard methods.

***cis*- and *trans*-2-(Phenylselenenyl)-2-*n*-amyl-3-methylcyclopentanone (4).** To a 100-mL, three-necked, round-bottomed flask containing a mixture of 0.60 g of oven-dried CuI (3.16 mmol) in 15 mL of anhydrous diethyl ether at 0 °C under a nitrogen atmosphere was added 4.42 mL of CH_3Li (6.63 mmol, 1.5 M). After the mixture was allowed to stir for 15 min, it was cooled to −20 °C with a dry ice/CCl_4 bath, and to it was added 0.50 g of **3** (3.1 mmol) in 10 mL of anhydrous ether. After 20 min, 50 mL of anhydrous THF, 6 mL of hexamethylphosphoramide (HMPA), and 4.50 g of *n*-amyl iodide (22.7 mmol) were sequentially added. The cooling bath was then removed, and the reaction mixture was allowed to stir for 36 h at room temp. The reaction was quenched by addition of 10 mL of 1:1 concentrated NH_4OH/saturated NH_4Cl solution. The bulk of the ether and THF was removed in vacuo, and the residue was extracted with ether (3 × 30 mL). The combined ether layer was washed with 1:1 concentrated NH_4OH/saturated NH_4Cl solution (3 × 50 mL), 10% HCl solution (3 × 20 mL), and water (2 × 25 mL). The solution was dried with $MgSO_4$, and the solvent was removed in vacuo, leaving 0.65 g of crude **4**. Further purification was achieved by chromatography on silica gel, which gave 0.59 g (85% yield) of **4** as a light yellow oil: ^1H NMR ($CDCl_3$) 2.92–0.96 (m, 21), 7.15–7.80 (m, 5); IR ($CHCl_3$) 1730 cm^{-1}; mass spectrum, *m/e* 324.

3-Methyl-2-(1-pentylidene)cyclopentanone (5) and Dihydrojasmone (2). To 15 mL of a CH_2Cl_2 solution containing 0.25 g (0.77 mmol) of a mixture of **4** and **5** at 0 °C was added three 0.20-mL portions of 30% H_2O_2 solution at 10-min intervals. Fifteen minutes after the final peroxide addition, the mixture was transferred to a separatory funnel, and the layers were separated. The organic layer was washed with saturated $NaHCO_3$ solution (5 mL) and water (5 mL), dried ($MgSO_4$), and stripped of its solvent in vacuo to give 0.115 g (93% yield) of an almost colorless liquid, which was shown by both NMR and gas chromatography (20% Carbowax 20M on Chromosorb P, 170 °C) to be a 65:35 mixture of **2** and **5**, respectively: ^1H NMR for **5**[10] ($CDCl_3$) 0.83 (t, J = 5 Hz, 3), 1.17 (d, J = 7 Hz, 3), 2.60–2.00 (m, 7),1.70–1.10 (m, 4), 6.70 (td, J = 6, 1 Hz, 1); IR ($CHCl_3$) 1705, 1650 cm^{-1}; mass spectrum, *m/e* 166; ^1H NMR for **2**[11] ($CDCl_3$) 0.87 (t, J = 5 Hz, 3), 1.70–1.10 (m, 8), 2.60–2.00 (m, 4), 2.08 (s, 3); IR ($CHCl_3$) 1705, 1650 cm^{-1}; mass spectrum, *m/e* 166.

Isomerization of a Mixture of 2 and 5 to 2. A mixture of 30 μL of *n*-BuOH, 15 μL of concentrated HCl, and 0.085 g (0.51 mmol) of **2** and **5** was heated for 1 h at 90 °C. The cooled reaction mixture was then poured onto solid $NaHCO_3$, and the resulting mixture was washed with pentane (5 × 5 mL). The combined pentane layers were washed with a small amount of water (4 × 1 mL) and dried ($MgSO_4$). After removal of the solvent in vacuo, 0.072 g (85% yield) of **2** remained. When **2** was isolated in this fashion, it contained no impurities which were detectable by GC (20% Carbowax 20M on Chromosorb P, 170 °C), unless, of course, the isomerization has not gone to completion.

3-Methyl-2-(phenylselenenyl)cyclopentanone (6). To a 250-mL round-bottomed flask containing a magnetic stirring bar were added under nitrogen 4.83 g (25.4 mmol) of cuprous iodide and 125 mL of dry ether. Methyllithium (34.4 mL, 1.6 M, 51.6 mmol) was added dropwise via syringe to the stirred solution at 0 °C. After 20 min the reaction was cooled to −20 °C, and 5 g (21.1 mmol) of 2-(phenylselenenyl)cyclopentenone (**3**) was added dropwise in 25 mL of dry ether. In 30 min the reaction mixture was added to 300 mL of 1:1 NH_4OH/saturated NH_4Cl and subjected to continuous (lighter than water) extraction with ether overnight. The extract was washed with water (1 × 50 mL), dried over $MgSO_4$, and stripped of solvent. Compound **6** (5.10 g, 20.1 mmol) was obtained as an orange oil in 95% yield: ^1H NMR ($CDCl_3$) 7.90–7.30 (m, 5), 3.25 (d, J = 7 Hz, 1), 2.00–2.80 (m, 5), 1.19 (d, J = 6 Hz, 3); IR ($CHCl_3$) 1730 cm^{-1}; mass spectrum, *m/e*

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(11) Synthetic applications of these selective enolate exchange processes will be the subject of future publications.
(12) For another example of nucleophilic attack on the selenium of an α-phenylselenenyl ketone, see ref 3.
(13) Stork, G.; Nelson, G. L.; Roussac, F.; Gringore, O. *J. Am. Chem. Soc.* **1971**, *93*, 3091. See also ref 14.
(14) Carvel, G. W.; Goodrich, B. S.; Laing, D. G. *Aust. J. Chem.* **1970**, *23*, 83.

254; precise mass calcd for $C_{12}H_{14}O^{80}Se$ m/e 254.020 96, found 254.021 01.

***cis*- and *trans*-3-Methyl-2-(phenylselenenyl)-2-(2-pentynyl)cyclopentanone (7).** To a round-bottomed flask containing 1.15 g (11.4 mmol) of diisopropylamine and two crystals of α,α'-bipyridyl in 10 mL of anhydrous THF at -78 °C was added 6.70 mL of 1.5 M *n*-BuLi (10.05 mmol) in hexane via syringe. The resulting solution was allowed to stir for 15 min. A second round-bottomed flask containing 1.70 g (6.70 mmol) of **6** and in 25 mL of anhydrous THF was cooled to -78 °C, and to it was slowly added the LDA solution, prepared in the first flask, until the color remained pink. After the solution was allowed to stir for 15 min, 2.2 mL of HMPA and 3.50 g of 1-bromo-2-pentyne were added. The reaction mixture was then allowed to stir for 2 h at -78 °C and an additional 10 h at room temperature. The reaction was then quenched by the addition of 10 mL of 10% HCl. The bulk of the THF was removed in vacuo, and the residue was extracted with ether (3 × 40 mL). The combined ether layers were washed sequentially with 10% HCl solution (3 × 10 mL), saturated $NaHCO_3$ solution (2 × 10 mL), and water (2 × 10 mL). The solution was dried with $MgSO_4$, and the solvent was removed in vacuo, leaving 2.05 g of **7**. The small amounts of impurities present were separated from the mixture via silica gel chromatography, which gave 2.00 g (96.4% yield) of **7**: ^1H NMR ($CDCl_3$) 7.71–7.13 (m, 5), 2.93–1.50 (m, 9), 1.34–0.97 (overlapping pair of d and t, 6); IR ($CHCl_3$) 1724 cm^{-1}; mass spectrum, m/e 320.

3-Methyl-2-(pent-2-ynylidene)cyclopentanone (8). To 15 mL of a CH_2Cl_2 solution containing 0.40 g of at 0 °C were added three 0.20-mL portions of 30% H_2O_2 solution at 10-min intervals. Fifteen minutes after the final peroxide addition, the mxiture was transferred to a separatory funnel, and the layers were separated. The organic layer was washed with saturated $NaHCO_3$ solution (3 mL) and water (3 mL), dried ($MgSO_4$), and stripped of its solvent in vacuo to give 0.22 g (100% yield) of **10**. The sample obtained from this procedure was spectroscopically pure: ^1H NMR ($CDCl_3$) 6.35 ("q", J = 2.5 Hz, 1) 3.25–2.97 (m, 1), 2.60–1.45 (m, 6), 1.31–1.10 (overlapping pair of d and t, 6); IR ($CHCl_3$) 2205, 1700, 1610 cm^{-1}; mass spectrum, m/e 162; precise mass calcd for $C_{11}H_{14}O$ m/e 162.104 66, found 162.110 78.

3-Methyl-2-(2-oxo-1-pentyl)cyclopent-2-enone (10). A mixture of 30 μL of *n*-BuOH, 15 mL of 50% H_2SO_4, and 0.10 g of **8** (2.62 mmol) was heated at 90 %C for 25 min. The cooled reaction mixture was then poured onto solid $NaHCO_3$, and the resulting mixture was washed with pentane (5 × 5 mL). The combined pentane layers were washed with a small amount of water (3 × 1 mL) and dried ($MgSO_4$). After removed of the solvent in vacuo, 0.08 g (80% yield) of **12** remained. Further purification was achieved via silica gel chromatography: ^1H NMR ($CDCl_3$) 0.83 (t, J = 6 Hz, 3), 1.58 (Br q J = 6 Hz, 2), 1.99, (s, 3), 2.65–2.40 (m, 4), 3.24 (br s, 2); IR ($CHCl_3$) 1700, 1650 cm^{-1}; mass spectrum, m/e 180.

5-(Phenylselenenyl)-3-methyl-2-(pent-2-ynyl)cyclopentanone (14). To a 100-mL round-bottomed flask containing 0.25 g (2.5 mmol) of diisopropylamine in 20 mL of anhydrous THF at -78 °C was added 1.2 mL of 1.5 M *n*-BuLi (1.8 mmol) in hexane via syringe. The resulting solution was allowed to stir for 15 min, at which time 1.0 g (3.14 mmol) of **7** and 2 mL of HMPA were added. The reaction mixture was stirred at -78 °C for 30 min and then allowed to slowly warm to room temperature. After being stirred at room temperature for 1 h, the reaction mixture was quenched with 1 mL of a saturated ammonium chloride solution. The THF was removed via a rotary evaporator, and the resulting residue was partitioned between ether (50 mL) and water (15 mL). The aqueous layer was washed twice with ether (25 mL). The combined ether layers were dried with $MgSO_4$ and stripped of solvent to give 1.0 g of **13** (mixture of epimers, 100% yield). This material was used in the next step of the sequence without any additional purification: ^1H NMR ($CDCl_3$) 7.79–7.20 (m, 5), 3.97–3.51 (m, 1), 2.85–1.50 (m, 8), 1.33–0.85 (m, 6).

5-(Pent-2-ynyl)-4-methylcyclopent-2-en-1-one (15). To 25 mL of a methylene chloride solution containing 1.0 g (3.14 mmol) of **14** were added six 1-mL portions of 30% H_2O_2 at 10-min intervals. Five minutes after the final peroxide addition, the mixture was transferred to a separatory funnel, and the layers were separated. The organic layer was washed sequentially with water (5 mL), saturated $NaHCO_3$ solution (5 mL), and again with water (5 mL). The solution was dried over $MgSO_4$ and evaporated to give 0.54 g of **15** which contained virtually no impurities. Complete purification was achieved via silica gel chromatography: (0.51 g (100% yeild); ^1H NMR ($CDCl_3$) 7.63–7.52 (dd, J = 7 Hz, J' = 2 Hz, 1), 6.17–6.05 (dd, J = 7 Hz, J' = 1.5 Hz, 1), 3.03–1.85 (m, 6), 1.27 (:, J = 7 Hz, 3), 1.08 (t, J = 6 Hz, 3); IR ($CHCl_3$) 1700, 1620, 1597 cm^{-1}; mass spectrum, m/e 162; precise mass calcd for $C_{11}H_{14}O$ m/e 162.104 66, found 162.107 66.

Dehydrojasmone (9).[8,9] A methanol solution (10 mL) containing 500 mg (3.10 mmol) of **15** and 100 mg (1.9 mmol) of sodium methoxide was allowed to stir at room temperature under nitrogen for 5 h. The reaction mixture was quenched with water (0.5 mL), and the bulk of the methanol was removed via a rotary evaporator. The residue was extracted with ether (3 × 20 mL). The combined organic layers were washed with water, dried with $MgSO_4$, and stripped of solvent in vacuo to give 0.5 g of crude **9**. Purification was achieved via silica gel chromatography: 440 mg (88% yield); ^1H NMR ($CDCl_3$) 3.06 (br s, 2), 2.60–1.93 (m with overlapping s at δ 2.20, 9), 1.05 (t, J = 6 Hz, 3); IR ($CHCl_3$) 1700, 1650 cm^{-1}.

***cis*-Jasmone (1).**[8,9] A 50-mg (3 mmol) sample of **9** in 1 mL of ethyl acetate was added to a mixture containing Lindlar catalyst in 2 mL of ethyl acetate under 1 atm of hydrogen. After a few minutes the hydrogen uptake ceased. After the catalyst was filtered off, the solution was stripped of its solvent to yield spectroscopically pure **1**: 47 mg (95% yield); ^1H NMR (CCl_4) 5.22 (td, J = 6 Hz, J' = 4 Hz, 2), 2.84 (d, J = 5 Hz 2), 2.20 (m, 6), 2.02 (s, 3), 0.97 (t, J = 7.5 Hz, 3).

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Registry No. **1**, 488-10-8; **2**, 1128-08-1; **3**, 71996-27-5; *cis*-**4**, 78763-71-0; *trans*-**4**, 78763-72-1; **5**, 78763-73-2; **6**, 78763-74-3; *cis*-**7**, 78763-75-4; *trans*-**7**, 78763-76-5; **8**, 78763-77-6; **9**, 7051-37-8; **10**, 78763-78-7; **14** (isomer 1), 78763-79-8; **14** (isomer 2), 78821-59-7; **15**, 78763-80-1; amyl iodide, 628-17-1; 1-bromo-2-pentyne, 16400-32-1.

Direct Amidation of Aromatic Compounds

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Comparatively few reports have appeared of direct aminations[1] or amidations (by NHCOR or NR'COR)[2] of aromatic rings. Wassmundt and Padegimas[3] reported in 1967 that an acylamido group could be directly introduced into the para position of anisole by heating with acetohydroxamic acid in polyphosphoric acid (PPA) as solvent (eq 1). The reported yield (57%) was obtained only when

$$ArH + CH_3C(O)NHOH \xrightarrow{PPA} ArNHC(O)CH_3 + H_2O$$

a large excess (10:1 molar ratio) of hydroxamic acid was used. The yield was sharply reduced when equimolar quantities of hydroxamic acid and the substrate were employed. The necessity for such a large molar ratio obviously diminishes the value of the method. Apart from an intramolecular example, anisole was the only substrate mentioned by Wassmundt and Padegimas. We have investigated this reaction in an effort to determine the optimum conditions and the scope.

(1) For a discussion, see: March, J. "Advanced Organic Chemistry", 2nd ed.; McGraw-Hill: New York, 1977; p 478.

(2) For some other direct amidations, see: Cadogan, J. I. G.; Rowley, A. G. *J. Chem. Soc., Perkin Trans. 1* **1975**, 1069. Abramovitch, R. A.; Singer, G. M. *J. Org. Chem.* **1974**, *39*, 1795. So, Y.-H.; Becker, J. Y.; Miller, L. L. *J. Chem. Soc., Chem. Commun.* **1975**, 262.

(3) Wassmundt, F. W.; Padegimas, S. J. *J. Am. Chem. Soc.* **1967**, *89*, 7131.

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