Application of Oxidative Aryl Migration in Organo-selenium and -tellurium Compounds to the Synthesis of 2-Arylpropanoic Acids

Sakae Uemura* and Shin-ichi Fukuzawa
Institute for Chemical Research, Kyoto University, Uji, Kyoto 611, Japan
Takayoshi Yamauchi,* Kaneaki Hattori, Shoichi Mizutaki, and Kentaro Tamaki
Research & Development Laboratory, Sakai Plant, Kyowa Hakko Kogyo Co. Ltd., Sakai, Osaka 590, Japan

The ethylene acetals of aryl α-phenylseleno- and α-phenyltelluro-ethyl ketones [aryl = p-XC_6H_4 (X = H, Me, Bu^t, Ph, Br) and 5-bromo-6-methoxy-2-naphthyl] have been prepared in 12—83% yields by treating the corresponding α-bromo compounds with diphenyl diselenide–sodium or diphenyl ditelluride–sodium, respectively, in tetrahydrofuran–dimethylformamide under reflux for 6—20 h, during which the bromine is substituted by the PhSe or PhTe group. This substitution is not observed when the $(PhM)_2$–$NaBH_4$–EtOH (M = Se, Te) system which is known as a source of PhM^- anion is used. Oxidation of the acetals thus formed with an excess of *meta*-chloroperbenzoic acid at 20—25 °C for 1 h affords hydroxyethyl 2-arylpropanoates in 56—86% yields *via* aryl group migration which are hydrolysed to 2-arylpropanoic acids, some of which are pharmaceutically important compounds. Overall isolated yields of 2-arylpropanoic acids are around 30—42% based on the starting propiophenones over 5 steps.

Quite recently it was reported that the treatment of alkyl phenyl selenides or tellurides with an excess of *meta*-chloroperbenzoic acid (MCPBA) in alcohol at room temperature affords the corresponding dialkyl ethers in high yields by the substitution of a PhSe or PhTe moiety with an alkoxy group.[1] The reaction was accompanied by phenyl migration when applied to selenides or tellurides having a phenyl group at a vicinal position to the PhSe or PhTe moiety (Scheme 1). We

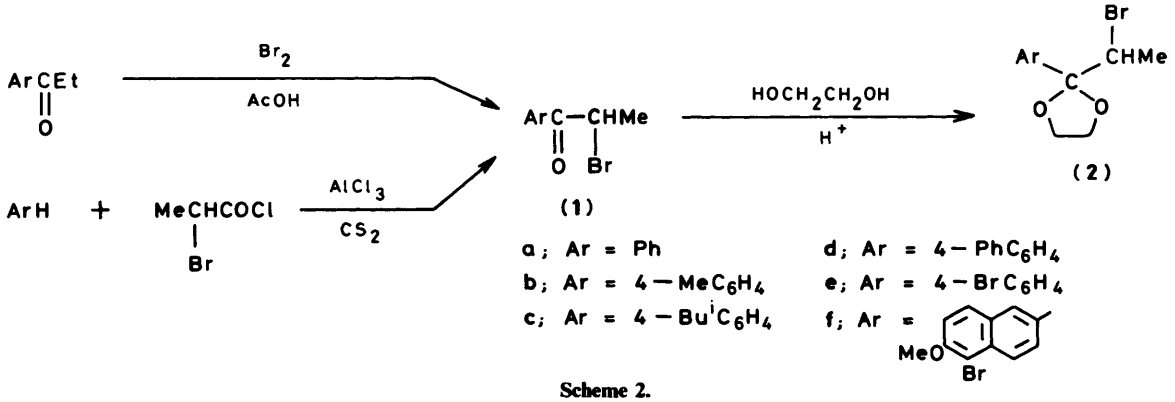
$$RCH_2CH_2MPh \xrightarrow[R'OH]{MCPBA} RCH_2CH_2OR'$$

$$\begin{matrix} PhCHCH_2MPh \\ | \\ Me \end{matrix} \xrightarrow[R'OH]{MCPBA} \begin{matrix} R'OCHCH_2Ph \\ | \\ Me \end{matrix} \quad (M = Se, Te)$$

Scheme 1.

successfully applied this methodology to the synthesis of 2-arylpropanoic acids from α-bromopropiophenones, some of the former being pharmaceutically important compounds[2] exhibiting anti-inflammatory and analgesic activities. Although many synthetic methods for the acids using aryl migration have been elaborated so far,[3] our report demonstrates the first example of such a method in the field of organo-selenium and -tellurium chemistry.[4]

First, the aryl 1-bromoethyl ketone (**1**) was prepared either by bromination of an aryl ethyl ketone at the α-position in acetic acid or by Friedel-Crafts acylation using 2-bromopropanoyl chloride [only for (**1d**)], and it was then converted into the corresponding ethylene acetal (**2**) with ethylene glycol in the presence of toluene-p-sulphonic acid under reflux (Scheme 2). The overall isolated yield of (**2**) from ketone or 2-bromopropanoyl chloride was 46—86% (see the Experimental section). When compound (**2**) was added to a tetrahydrofuran–dimethylformamide solution of diphenyl diselenide or diphenyl ditelluride and sodium wire under a N_2 atmosphere and the resulting mixture was stirred under reflux for 6—20 h, the bromine was substituted by the PhSe or PhTe group to afford α-(phenylseleno)ethyl- or α-(phenyltelluro)ethyl-dioxolane derivative (**3**) in 70—83% isolated yield (for M=Se) and in 12—62% isolated yield (for M=Te) (Scheme 3, Table 1). This substitution did not proceed by using the $(PhM)_2$–$NaBH_4$–EtOH (M=Se, Te) system which is known as a source of PhM^- anion for substitution of normal primary and secondary alkyl halides, and the starting compound (**2**) was recovered almost quantitatively. The result shows that nucleophilicity of PhM^- is much weaker in the latter case than in the former. Compound (**3**) is stable in air when M=Se, but is slightly air-sensitive when M=Te. This seems to be one reason why the isolated yield from the preparation of (**3**; M=Te) was always lower than that of (**3**; M=Se). In fact, in the synthesis of (**3d**; M=Te) we isolated a vinylic compound (**5d**) in 27% yield together with the expected product (**3d**) (45%) (see the Experimental section). In all other cases the formation of

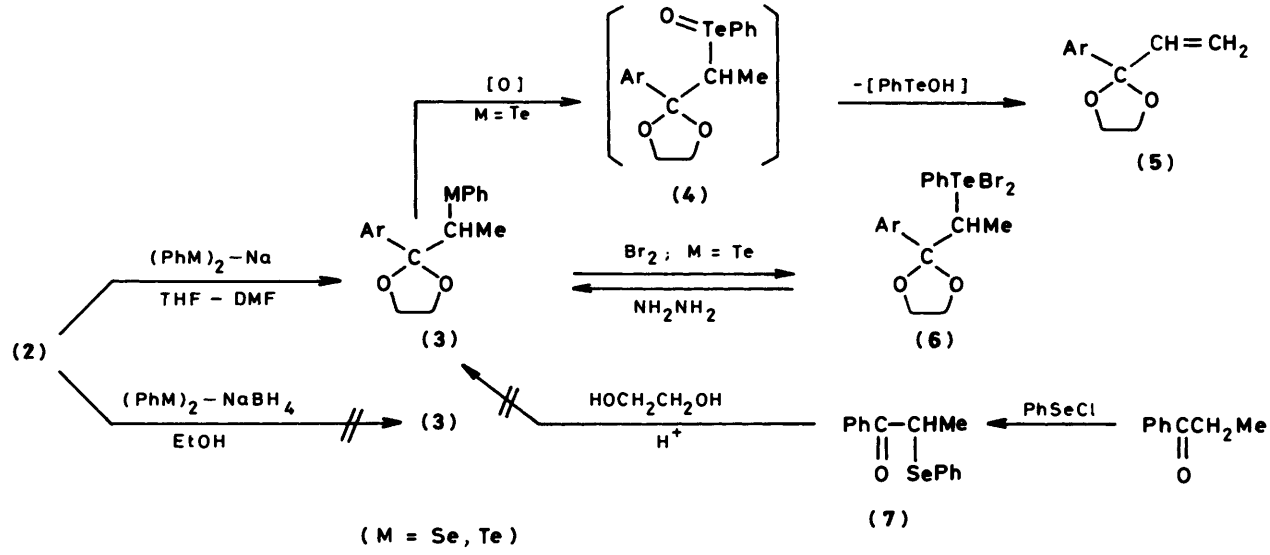


Scheme 2.

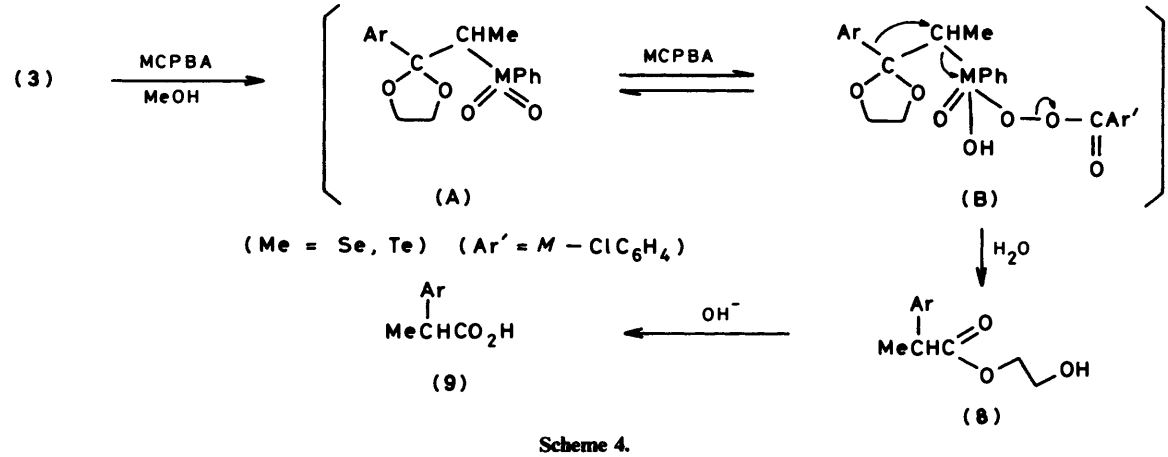
Table 1. 2-Arylpropanoic acids (**9**) from aryl ethyl ketones (**1**) *via* compounds (**2**), (**3**), and (**8**)[a]

Starting acetal (**2**)	Reaction time (h)[b]	Yield (%) of (**3**)[c]	Yield (%) of (**8**)[d]	Yield (%) of (**9**)[e]	M.p. (°C)
a	20	**a**; M=Se 75	**a** 80	**a** 81	15—15.5(15—16.5)[17]
a	20	**a**; M=Te 62	**a** 71		
b	7	**b**; M=Se 83	**b** 86	**b** 91	36—37(34—35)[18]
b	6.5	**b**; M=Te 34	**b** 62		
c	20	**c**; M=Se 70	**c** 82	**c** 91	75—76(75—77)[19]
c	20	**c**; M=Te 50	**c** 75		
d	7	**d**; M=Se 81	**d** 56	**d** 87	146—147(145—147)[20]
d	6	**d**; M=Te 45	**d** 79		
e	8	**e**; M=Se 74	**e** 85		
f	11	**f**; M=Te 12	**f** 58		

[a] Yields of (**1**) and (**2**) are shown in the Experimental section. [b] At reflux temperature of THF–DMF. [c] Isolated yield based on (**2**). [d] Isolated yield based on (**3**). Reaction conditions; at 20—25 °C for 10 min—1 h. [e] Isolated yield based on (**8**). The reported m.p. (°C) is in parenthesis.



Scheme 3.



Scheme 4.

variable amounts of such vinylic compounds was observed by ^{1}H n.m.r. spectroscopy and t.l.c., although their isolation and characterization were not carried out. The reaction scheme of an air-oxidation of compound (**3**; M=Te) to the corresponding telluroxide (**4**) followed by a telluroxide elimination[5] accounts for the formation of compound (**5**). It was possible to store (**3**; M=Te) as a stable compound in the form of a dibromide (**6**) by treatment with bromine, and the reduction of (**6**) with hydrazine hydrate regenerated compound (**3**) quantitatively (see the Experimental section). Attempts to prepare compound (**3a**; M=Se) by acetalization of α-(phenylseleno)propiophenone (**7**) with ethylene glycol, prepared separately by seleniation of propiophenone with benzeneselenenyl chloride, resulted in partial decomposition to propiophenone and diphenyl diselenide, with none of the expected compound (**3a**; M=Se) being formed.

Table 2. Spectral and combustion analytical data of compound (3)

Compound[a]	δ_H(90 MHz)	δ_C(25.1 MHz)	Found (%) (Requires) C	H
(**3a**; M=Se)	1.33 (3 H, d, *J* 7), 3.72 (1 H, q, *J* 7), 3.8—4.2 (4 H, m), 7.1—7.6 (10 H, m)		60.9 (61.3)	5.35 (5.4)
(**3b**; M=Se)	1.32 (3 H, d, *J* 7), 2.32 (3 H, s), 3.7—4.2 (4 H, m), 3.68 (1 H, q, *J* 7), 7.0—7.6 (9 H, m)	18.2 (q), 21.2 (q), 48.9 (d), 65.2 (t), 65.4 (t), 111.2 (s), aromatic signals	62.3 (62.2)	5.80 (5.80)
(**3c**; M=Se)	0.86 (6 H, d, *J* 7), 1.30 (3 H, d, *J* 7), 1.80 (1 H, m), 2.44 (2 H, d, *J* 7), 3.66 (1 H, q, *J* 7), 3.8—4.2 (4 H, m), 7.0—7.6 (9 H, m)		64.9 (64.8)	6.7 (6.7)
(**3d**; M=Se)	1.4 (3 H, d, *J* 7), 3.76 (1 H, q, *J* 7), 3.8—4.3 (4 H, m), 7.2—7.7 (9 H, m)		67.1 (67.5)	5.4 (5.4)
(**3e**; M=Se)	1.34 (3 H, d, *J* 7), 3.62 (1 H, q, *J* 7), 3.8—4.2 (4 H, m), 7.1—7.6 (9 H, m)	17.9 (q), 48.5 (d), 65.3 (t), 65.5 (t), 110.8 (s), aromatic signals	49.4 (49.5)	4.1 (4.15)
(**3a**; M=Te)	1.39 (3 H, d, *J* 7), 3.60—4.08 (5 H, m), 7.0—7.73 (10 H, m)		53.4 (53.5)	4.6 (4.75)
(**3b**; M=Te)	1.47 (3 H, d, *J* 7), 2.35 (3 H, s), 3.97 (1 H, q, *J* 7), 3.7—4.2 (4 H, m), 7.1—7.8 (9 H, m)	19.6 (q), 21.1 (q), 33.8 (d), 64.9 (t), 65.3 (t), 111.8 (s), aromatic signals	54.6 (54.6)	5.1 (5.1)
(**3c**; M=Te)	0.90 (6 H, d, *J* 7), 1.47 (3 H, d, *J* 7), 1.87 (1 H, m), 2.47 (2 H, m), 3.70—4.13 (5 H, m), 7.0—7.8 (9 H, m)		57.9 (57.6)	5.9 (6.0)
(**3d**; M=Te)	1.50 (3 H, d, *J* 7), 3.7—4.2 (4 H, m), 3.88 (1 H, q, *J* 7), 7.1—7.8 (14 H, m)		60.1 (60.45)	4.7 (4.6)
(**3f**; M=Te)	1.50 (3 H, d, *J* 7), 3.98 (3 H, s), 3.7—4.2 (5 H, m), 7.0—8.2 (10 H, m)	19.5 (q), 33.5 (d), 57.1 (q), 65.0 (t), 65.5 (t), 111.7 (s), aromatic signals	49.1 (48.85)	4.0 (3.9)

[a] All compounds except (**3b**; M=Te) (pale yellow crystals, m.p. 105—106 °C) are yellow oils.

Table 3. Spectral and combustion analytical data of (8)

Compound	M.p. (°C)	δ_H(90 MHz)	δ_C(25.1 MHz)	Found (%) (Requires) C	H
(**8a**)	Oil	1.48 (3 H, d, *J* 7), 2.10 (1 H, br, s), 3.60—4.18 (5 H, m), 7.20 (5 H, s)		67.9 (68.0)	7.1 (7.3)
(**8b**)	Oil	1.26 (1 H, br, s), 1.48 (3 H, d, *J* 7), 2.32 (3 H, s), 3.72 (1 H, q, *J* 7), 3.6—4.2 (4 H, m), 7.15 (4 H, s)	18.5 (q), 20.9 (q), 45.0 (d), 60.8 (t), 66.2 (t), 175.0 (s), aromatic signals	68.7 (69.2)	7.8 (7.7)
(**8c**)	Oil	0.87 (6 H, d, *J* 7), 1.47 (3 H, d), 1.80 (1 H, m), 2.03 (1 H, br, s), 2.41 (2 H, d, *J* 7), 3.60—4.18 (5 H, m), 6.99 (2 H, d), 7.12 (2 H, d)		71.8 (72.0)	8.7 (8.9)
(**8d**)	75	1.57 (3 H, d, *J* 7), 1.86 (1 H, br s,), 3.75 (1 H, q, *J* 7), 3.8—4.3 (4 H, m), 7.2—7.7 (9 H, m)		75.4 (75.5)	6.7 (6.7)
(**8e**)	Oil	1.48 (3 H, d, *J* 7), 2.38 (1 H, br, s) 3.74 (1 H, q, *J* 7), 3.7—4.3 (4 H, m), 7.1—7.8 (4 H, m)		48.0 (48.4)	4.8 (4.8)
(**8f**)	83	1.55 (3 H, d, *J* 7), 3.58 (1 H, br s,), 3.7—4.3 (5 H, m), 3.93 (3 H, s), 7.5—8.2 (5 H, m)	18.4 (q), 45.1 (d), 57.0 (q), 60.8 (t), 66.3 (t), 174.6 (s), aromatic signals	54.3 (54.4)	4.7 (4.85)

Compound (**3**) was then treated with an excess of MCPBA (5—6 equiv.) in methanol at room temperature for 10 min to 1 h. Normal work-up procedure of the resulting clear homogeneous solution afforded the hydroxyethyl ester of 2-arylpropanoic acid (**8**) in 56—86% isolated yield based on (**3**), the reactivity of both selenium and tellurium compounds being nearly the same (Table 1). The reaction seems to proceed *via* a selenone or tellurone intermediate (A), or more preferably its MCPBA adduct (B) in which aryl group migration occurs as shown in Scheme 4.[1] Other oxidizing agents such as H_2O_2, $NaIO_4$, and Bu^tOOH, were not effective for this oxidative rearrangement. Direct oxidation of compound (**7**) with MCPBA in methanol, followed by the same work-up procedure as above, produced only small amounts of several unidentified compounds, none of which were consistent with (**8**) or the analogous ester. Alkaline hydrolysis of compound (**8**) readily afforded the corresponding acid (**9**) in over 80% isolated yield based on (**8**) (Table 1).

The present method was not applied to the corresponding sulphur analogue, and thus the compound (**3a**; M=S) did not

give any of the expected product (**8**) when it was treated with an excess of MCPBA under various conditions.

Experimental

^{1}H N.m.r. spectra were recorded with Varian EM-360 (60 MHz), JEOL FX-90 (90 MHz), and JEOL FX-100 (100 MHz) instruments on solutions in $CDCl_3$ with Me_4Si as an internal standard. ^{13}C N.m.r. spectra were taken at 25.1 MHz with a JEOLCO ^{13}C Fourier transform n.m.r. system (JNM FX-100) and were recorded on solutions in $CDCl_3$, after 350—1000 pulses with intervals of 0.8—3.0 s. I.r. spectra were recorded with a Shimadzu I.R.-435 spectrometer. G.l.c. analyses were carried out using a Shimadzu 4CMPF apparatus using EGSS-X(15%)-Chromosorb-W (1 and 3 m) and PEG-6000(25%)-Chromosorb-W (1 m) columns (N_2 as carrier gas). Melting points were determined with a Yanagimoto MP micro melting point determination apparatus and were uncorrected.

All organic and inorganic materials were commercial products. Diphenyl diselenide (purity: *ca.* 99%) and benzeneselenenyl chloride (purity: *ca.* 98%) were obtained from Aldrich Chemical Co. Diphenyl ditelluride was prepared by a reported method from tellurium and phenylmagnesium bromide.[6]

Preparation of Aryl 1-*Bromoethyl Ketones* (**1**).—The compounds were generally prepared by following a literature method for the preparation of *p*-bromophenacyl bromide.[7] To a stirred solution of aryl ethyl ketones (100 mmol) and glacial acetic acid (50 ml) was added dropwise bromine (17.0 g, 106 mmol), keeping the temperature below 20 °C. The reaction mixture was then stirred at 30 °C for 2 h, during which period the brown colour of the mixture faded out. For the preparation of (**1f**), ethyl 6-methoxynaphthalen-2-yl ketone was employed as the starting ketone. The compounds (**1**) were isolated by the normal work-up procedure, their isolated yields and characterization being as follows: (**1a**): (92%), b.p. 63 °C/0.15 Torr (lit.,[8] b.p. 125—130 °C/10 Torr); δ_H(90 MHz) 1.88 (3 H, d), 5.28 (1 H, q), and 7.32—8.08 (5 H, m); (**1b**): (54%), m.p. 79.5 °C (lit.,[9] m.p. 80 °C); δ_H(90 MHz) 1.85 (3 H, d), 2.41 (3 H, s), 5.23 (1 H, q), and 7.20—7.90 (4 H, m); (**1c**): (87%), m.p. 65 °C (lit.,[10] m.p. 67 °C); δ_H(90 MHz) 0.89 (6 H, d), 1.75 (3 H, d), 1.8 (1 H, m), 2.53 (2 H, d), 5.20 (1 H, q), and 7.1—8.1 (4 H, m); (**1e**); 98%, m.p. 85 °C (lit.,[11] m.p. 84—84.5 °C); δ_H(90 MHz) 1.87 (3 H, d), 5.17 (1 H, q), 7.5—7.9 (4 H, m); (**1f**): (80%), m.p. 168 °C (lit.,[10] m.p. 168—170 °C); δ_H(90 MHz) 1.95 (3 H, d), 4.04 (3 H, s), 5.48 (1 H, q), and 7.3—8.5 (5 H, m).

Preparation of Biphenyl-4-yl 1-*Bromoethyl Ketone* (**1d**).—To a mixture of anhydrous aluminium chloride (7.4 g, 55 mmol) and biphenyl (7.7 g, 50 mmol) in carbon disulphide (29 ml) was added dropwise 2-bromopropanoyl chloride (9.43 g, 55 mmol) with stirring at room temperature. After the mixture had been stirred at this temperature for 1 h, it was poured onto crushed ice (50 g) and extracted with ethyl acetate (2 × 50 ml). The extract was washed with saturated aqueous $NaHCO_3$ (50 ml) and brine (50 ml), and then dried (Na_2SO_4). Evaporation of the solvent under reduced pressure left a solid which was recrystallized from methanol to give the pure compound (**1d**); m.p. 84 °C (lit.,[12] m.p. 79 °C), (12.9 g, 89%); δ_H(90 MHz) 1.91 (3 H, d), 5.26 (1 H, q), and 7.3—8.1 (9 H, m).

Preparation of the Ethylene Acetals of Aryl 1-*Bromoethyl Ketones* (**2**).—Typical experimental procedure is as follows. To a solution of 1-bromoethyl 5-bromo-6-methoxynaphthalen-2-yl ketone (**1f**) (29.3 g, 78.8 mmol) in toluene (200 ml) were added ethylene glycol (31 g) and toluene-*p*-sulphonic acid (2 g), and the resulting mixture was then stirred under reflux for 24 h, during which period the water produced was distilled off as the toluene azeotrope. The light brown solution was cooled, and the separated organic layer was washed with brine and dried (Na_2SO_4). Evaporation of the solvent left a white solid of 2-(1-bromoethyl)-2-(5-bromo-6-methoxynaphthalen-2-yl)-1,3-dioxolane (**2f**); m.p. 95 °C (from methanol) (lit.,[10] m.p. 103—104 °C) (28.4 g, 87%). The isolated yield and characterization of other compounds (**2**) are as follows: (**2a**): (90%), b.p. 83 °C/0.2 Torr (lit.,[13] b.p. 112 °C/0.7 Torr); δ_H(90 MHz) 1.59 (3 H, d), 3.7—4.2 (4 H, m), 4.38 (1 H, q), and 7.2—7.6 (5 H, m); 2-(1-*bromoethyl*)-2-(p-*tolyl*)-1,3-*dioxolane* (**2b**) (86%), b.p. 132 °C/2.0 Torr, δ_H(90 MHz) 1.58 (3 H, d), 2.36 (3 H, s), 3.7—4.2 (4 H, m), 4.36 (1 H, q), 7.1—7.5 (4 H, m) (Found: C, 52.95; H, 5.6. $C_{12}H_{15}BrO_2$ requires C, 53.15; H, 5.6%); (**2c**); 92%, oil (lit.,[14] b.p. 103—105 °C/0.5 Torr); δ_H (90 MHz) 0.90 (6 H, d), 1.58 (3 H, d), 1.87 (1 H, m), 2.48 (2 H, d), 3.8—4.2 (4 H, m), 4.38 (1 H, q), 7.06 (2 H, d), and 7.39 (2 H, d); 2-*biphenyl*-4-*yl*-2-(1-*bromoethyl*)-1,3-*dioxolane* (**2d**) (97%), m.p. 71 °C, δ_H(90 MHz) 1.62 (3 H, d), 3.8—4.3 (4 H, m), 4.40 (1 H, q), and 7.3—7.7 (9 H, m) (Found: C, 61.0; H, 5.1. $C_{17}H_{17}BrO_2$ requires C, 61.3; H, 5.1%); 2-(1-*bromoethyl*)-2-(4-*bromophenyl*)-1,3-*dioxolane* (**2e**) (85%), m.p. 50 °C, δ_H(90 MHz) 1.58 (3 H, d), 3.8—4.2 (4 H, m), 4.3 (1 H, q), and 7.4—7.5 (4 H, m) (Found: C, 39.6; H, 3.5. $C_{11}H_{12}Br_2O_2$ requires C, 39.3; H, 3.6%).

Preparation of 2-*Aryl*-2-(1-*phenylseleno*)*ethyl*-1,3-*dioxolane* (**3**; M = Se) *and* 2-*Aryl*-2-(1-*phenyltelluro*)*ethyl*-1,3-*dioxolane* (**3**; M = Te).—Typical experimental procedure is as follows. To a solution of diphenyl diselenide (1.56 g, 5 mmol) in THF (10 ml) was added sodium wire (0.3 g, 13 mmol) under N_2 at 20 °C. After the mixture had been heated under reflux for 2 h with stirring, a solution of compound (**2b**) (1.35 g, 5 mmol) in DMF (15 ml) was added and the resulting mixture was stirred at reflux for 6 h. After having been cooled, the mixture was treated with brine and extracted with $CHCl_3$(3 × 50 ml), and the extract was dried (Na_2SO_4). Evaporation of the solvent left a yellow oil which was subjected to column chromatography on SiO_2-[hexane–ethyl acetate (10:1) as the eluant] to give a yellow oil of 2-(4-*tolyl*)-2-(1-*phenylseleno*)*ethyl*-1,3-*dioxolane* (**3b**; M = Se) (1.44 g, 83%). For the preparation of the tellurium analogue, a similar procedure was employed but using diphenyl ditelluride in the place of diphenyl diselenide (*vide infra*). All compounds are new and their isolated yields are shown in Table 1. Their spectral and combustion analytical data are summarized in Table 2.

Preparation of 2-*Phenyl*-2-(1-*phenyltelluro*)*ethyl*-1,3-*dioxolane* (**3a**; M = Te) *and its Dibromide* (**6a**).—A mixture of diphenyl ditelluride (2.05 g, 5 mmol) and sodium wire (0.46 g, 20 mmol) was stirred in tetrahydrofuran (10 ml) under N_2 at reflux temperature for 7 h to afford a red-purple solution. To this solution were added successively, compound (**2a**) (1.81 g, 7 mmol) and dimethylformamide (15 ml) and the resulting mixture was stirred under reflux for 20 h, during which period the colour of the mixture turned brown and a pale brown precipitate was formed. The cooled mixture was then treated as described above. A yellow residue was subjected to column chromatography on SiO_2 to give diphenyl ditelluride (0.75 g, 1.83 mmol) (hexane as the eluant) and a mixture of 2-*phenyl*-2-(1-*phenyltelluro*)*ethyl*-1,3-*dioxolane* (**3a**; M = Te), compound (**2a**), and propiophenone[hexane–ethyl acetate (10:1)]. This mixture was dissolved in $CHCl_3$ and then treated with bromine. Evaporation left a yellow oil which was solidified by addition of pentane. The yellow solid was collected by filtration and identified as *the dibromide* (**6a**) *of compound* (**3a**; M = Te), m.p. 158—160 °C, (2.35 g, 62%), δ_H (100 MHz) 1.78 (3 H, d, *J* 7.3 Hz), 3.60—4.02 (2 H, m), 4.09—4.43 (2 H, m), 4.95 (1 H, q, *J* 7.3 Hz), 7.2—7.44 (6 H, m), 7.48—7.64 (2 H, m), and 8.0—8.2 (2 H, m) (Found: C, 37.6; H, 3.3. $C_{17}H_{18}Br_2O_2Te$ requires C, 37.7; H, 3.35%). The treatment of this dibromide with hydrazine

hydrate[15] afforded compound (**3a**; M = Te) quantitatively as a yellow-orange oil (see Table 2).

Oxidation of Compound (**3**) *with* meta-*Chloroperbenzoic Acid to* 2-*Hydroxyethyl Arylpropanoate* (**8**).—A typical example is as follows. To a solution of the dioxolane (**3b**; M = Se) (1.04 g, 3.0 mmol) in methanol (10 ml) was added solid *meta*-chloroperbenzoic acid (3.23 g; 80% purity; 15 mmol) portion by portion at 20—25 °C and the resulting solution was stirred at that temperature for 1 h. To the resulting transparent solution were added 10% aqueous $Na_2S_2O_3$ (20 ml) and 10% aqueous $NaHCO_3$ (20 ml) successively, and the products were extracted with diethyl ether (3 × 40 ml) and the extract was dried ($MgSO_4$). Evaporation of the solvent under reduced pressure left a yellow oil which was subjected to column chromatography on SiO_2 [hexane–ethyl acetate (10:1 ~ 5:1) as the eluant] to give 2-*hydroxyethyl* 2-p-(*tolyl*)*propanoate* (**8b**) as a viscous oil, (0.495 g, 86%). All 2-hydroxyethyl esters (**8**) are new and their isolated yields are shown in Table 1. Their spectral and combustion analytical data are summarized in Table 3.

Preparation of 2-(*p-tolyl*)-2-(1-*phenylthio*)*ethyl*-1,3-*dioxolane* (**3b**; M = S).—To a solution of thiophenol (1.65 g, 15 mmol) in THF (15 ml) was added sodium wire (0.46 g, 20 mmol) under a flush of N_2 at 20 °C and the mixture was stirred at reflux temperature for 2 h under N_2. To the resulting light yellow solution was added a solution of compound (**2b**) (2.71 g, 10 mmol). The mixture was then refluxed for 4.5 h under N_2 with stirring. After being cooled, the resulting mixture was treated as described above for the synthesis of (**3**; M = Se, Te) to give 2-(*p-tolyl*)-2-(1-*phenylthio*)*ethyl*-1,3-*dioxolane* (**3b**; M = S) as a yellow oil, (1.85 g, 62%), δ_H(90 MHz) 1.25 (3 H, d), 2.20 (3 H, s), 3.68 (1 H, q), 3.68 (1 H, q), 3.8—4.2 (4 H, m), and 7.1—7.5 (9 H, m) (Found: C, 71.5; H, 6.7. $C_{18}H_{20}O_2S$ requires C, 72.0; H, 6.7%).

Hydrolysis of Compound (**8**) *to* 2-*Arylpropanoic Acids* (**9**).—A general procedure is as follows. A mixture of compound (**8**) (30 mmol) and aqueous 2M-NaOH (20 ml) was heated under reflux for 2—10 h until the reaction mixture became clear. After the cooled mixture had been washed with $CHCl_3$(2 × 10 ml), the water layer was acidified with concentrated HCl to afford a white precipitate of compound (**9**) which was collected by filtration and recrystallized from aqueous acetic acid. Isolated yields and melting points of the acids (**9**) are shown in Table 1.

Preparation of 2-*Biphenyl*-4-*yl*-2-(1-*phenyltelluro*)*ethyl*-1,3-*dioxolane* (**3d**; *M = Te*) *and Isolation of* 2-*Biphenyl*-4-*yl*-2-*vinyl*-1,3-*dioxolane* (**5d**).—A mixture of diphenyl ditelluride (4.09 g, 10 mmol), sodium wire (0.60 g, 26 mmol), and dry THF (20 ml) was refluxed under N_2 for 3 h with stirring. To the resulting brown solution was added compound (**2d**) (5.62 g, 16.9 mmol) and the mixture was refluxed for a further 1.5 h. To the solution was added dry DMF (20 ml) and the mixture was refluxed for 14 h. The cooled solution was then treated with methanol (2 ml) to remove unchanged sodium. The mixture was then poured into brine (200 ml) and extracted with $CHCl_3$ (3 × 100 ml), and the extract was dried (Na_2SO_4). Evaporation of the $CHCl_3$ left a residue which was subjected to column chromatography on SiO_2 to give diphenyl ditelluride (0.68 g, 1.66 mmol) (hexane as the eluant) and a mixture of products (4.87 g) [hexane–ethyl acetate (20:1)]. The mixture was separated by a reverse phase chromatography [Lorbar column LiChroprep RP-8; methanol–water (5:1) as the eluant] to give 2-*biphenyl*-4-*yl*-2-(1-*phenyltelluro*)*ethyl*-1,3-*dioxolane* (**3d**; M = Te) (3.48 g, 45%) and 2-*biphenyl*-4-*yl*-2-*vinyl*-1,3-*dioxolane* (**5d**) (1.16 g, 27.2%) in pure forms, respectively. Compound (**5d**) showed δ_H (90 MHz) 4.3 (2 H, s), 4.7 (2 H, s), 5.28 (1 H, dd, *J* 10 and 2 Hz), 5.44 (1 H, dd, *J* 17 and 2 Hz), 6.12 (1 H, dd, *J* 17 and 10 Hz), and 7.35—7.65 (9 H, m).

Preparation of 1-(*Phenylseleno*)*propiophenone* (**7**) *and its Attempted Acetalization and Oxidation.*—To a solution of propiophenone (2.01 g, 15 mmol) in ethyl acetate (40 ml) was added a solution of benzeneselenenyl chloride (2.88 g, 15 mmol) in ethyl acetate (10 ml), and the resulting solution was stirred for 3 h under reflux.[16] The cooled solution was washed with aqueous $NaHCO_3$(2 × 50 ml) and brine, and dried ($MgSO_4$). Evaporation of the solvent left an oily residue which was subjected to column chromatography [SiO_2; hexane–ethyl acetate (10:1) as the eluant] to give the pure compound (**7**) as a yellow oil (2.6 g, 60%), δ_H (60 MHz) 1.53 (3 H, d), 4.50 (1 H, q), 6.8—7.3 (8 H, m), and 7.5—7.8 (2 H, m).

A mixture of compound (**7**) (1.45 g, 5 mmol), trimethyl orthoformate (1.06 g, 10 mmol), toluene-*p*-sulphonic acid (0.2 g), and methanol (20 ml) was stirred overnight at 25 °C. The resulting yellow solution was treated with aqueous $NaHCO_3$ and then extracted with diethyl ether (3 × 30 ml). G.l.c. and t.l.c. analyses of the extract showed the presence of diphenyl diselenide and propiophenone; neither the expected dimethyl acetal nor the starting ketone being detected. A similar phenomenon was observed when compound (**7**) was treated with ethylene glycol in benzene at reflux for 5 h in the presence of the acid, none of the expected acetal (**3a**; M = Se) being obtained.

A mixture of compound (**7**) (0.29 g, 1 mmol), *meta*-chloroperbenzoic acid (1.06 g, 80% purity, 5 mmol), and methanol (10 ml) was stirred at 20—25 °C for 1 h. The mixture was then treated with brine and extracted with diethyl ether 3 × 50 ml). The extract was washed successively with aqueous $Na_2S_2O_3$, aqueous $NaHCO_3$, and brine, and dried ($MgSO_4$). G.l.c. analysis of the extract revealed the presence of at least six unidentified compounds, none of which corresponded to methyl 1-phenylpropanoate.

References

1 S. Uemura and S. Fukuzawa, *J. Chem. Soc., Perkin Trans.* 1, 1985, 471, and references therein.
2 For example, T. Y. Shen, *Angew. Chem., Int. Ed. Engl.*, 1972, **11**, 460.
3 C. Giordano, G. Castaldi, and F. Uggeri, *Angew. Chem., Int. Ed. Engl.*, 1984, **23**, 413.
4 Preliminary communication, S. Uemura, S. Fukuzawa, T. Yamauchi, K. Hattori, S. Mizutaki, and K. Tamaki, *J. Chem. Soc., Chem. Commun.*, 1984, 426.
5 S. Uemura, K. Ohe, and S. Fukuzawa, *Tetrahedron Lett.*, 1985, **26**, 895.
6 W. S. Haller and K. J. Irgolic, *J. Organomet. Chem.*, 1972, **38**, 97.
7 W. D. Langley, *Org. Synth.*, Coll. Vol. 1, 1948, p. 127.
8 F. Kunckell and W. Dettmar, *Chem. Ber.*, 1903, **36**, 771.
9 A. L. Wilds and A. L. Meader, Jr., *J. Org. Chem.*, 1948, **13**, 773.
10 C. Giordano, A. Belli, F. Uggeri, and G. Villa, Eur. Pat. Appl. EP 34, 841/1981 (*Chem. Abstr.*, 1982, **96**, P34940d).
11 M. A. Collet, *C. R. Seances Acad. Sci.*, 1898, **126**, 1577.
12 S. Machlis and K. C. Blanchard, *J. Am. Chem. Soc.*, 1935, **57**, 176.
13 R. R. Frame and W. Faulconer, *J. Org. Chem.*, 1971, **36**, 2048.
14 J. Svoboda, J. Paleček, V. Dědek, and J. Mostecký, *Collect. Czech. Chem. Commun.*, 1984, **49**, 1515.
15 S. Uemura, S. Fukuzawa, and A. Toshimitsu, *J. Organomet. Chem.*, 1983, **250**, 203.
16 K. B. Sharpless, R. F. Lauer, and A. Y. Teranishi, *J. Am. Chem. Soc.*, 1973, **95**, 6137.
17 A. Fredga and S. Wideqvist, *Acta Chem. Scand.*, 1947, **1**, 860.
18 H. Rupe and Fr. Wiederkehr, *Helv. Chim. Acta*, 1924, **7**, 658.
19 Boots Pure Drug Co. Ltd., Belg. Pat. 621, 255/1963 (*Chem. Abstr.*, 1963, **59**, 8660).
20 F. F. Blicke and N. Grier, *J. Am. Chem. Soc.*, 1943, **65**, 1727.

Received 17*th January* 1986; *Paper* 6/127