An Efficient and Mild Method for the Dehydrogenation of Spiroenones to Spirodienones via Organoselenium Reagents

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In connection with another problem, we required an efficient synthetic procedure for the conversion of [4.5]spiroenones **1** to the corresponding dienones **4**, a transformation which is often afflicted with concomitant rearrangement to non-spiro derivatives[1]. Thus, although several procedures are available for such dehydrogenations[2], applications to

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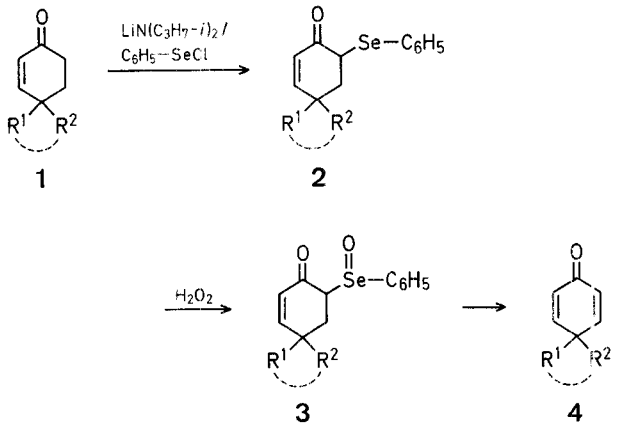
[4.5]-spiro systems are conspicuously absent. Indeed, several attempts (i.e. DDQ[2a,b], phenyl selenic anhydride[2c], palladium(II) derivatives[2d]) failed with substrates and forced an investigation of alternative approaches. This communication describes a successful solution to the problem which also provides an efficient, high yielding and general procedure for the dehydrogenation of less troublesome enones. The method relies on the mild and facile elimination of the benzeneseleninyl group[3] which is generated via α-benzeneselenation of the enones[4] and subsequent oxidation with dilute hydrogen peroxide[5].



Results for structurally varient examples are presented in the Table. The requisite phenyl selenides **2** are most efficiently generated by treatment of the ketone enolates of **1** (produced via lithium diisopropylamide) with benzeneselenyl chloride[3]. Direct benzeneselenylation of the ketones with benzeneselenyl chloride resulted in inferior yields especially with derivatives containing additional double bonds since competitive attack occurs on the isolated alkenes[3b].

Dehydrogenation of Enones to Dienones; Conversion of Enone 1a to Dienone 4a:

A solution of lithium diisopropylamide is prepared in tetrahydrofuran (40 ml) from the amine (1.35 ml, 9.6 mmol) and methyllithium (6.4 ml of 1.5 molar solution, 9.6 mmol) at −78 °C. To this is added, under nitrogen, a solution of the enone **1a**[4] (1.30 g, 8.7 mmol). After 10 min, a solution of benzeneselenyl chloride (1.80 g, 9.6 mmol) is added and the yellow solution stirred for 45 min while the temperature is allowed to rise to 0 °C. A solution containing 30% hydrogen peroxide (4.9 g) in water (10 ml) is added dropwise at such a rate that the temperature is maintained at 25 °C and stirring is continued for 1.5 h. Sodium hydrogen sulfite (5 g) is added slowly *(caution; foaming)* and the mixture stirred for 30 min. The mixture is diluted with water (50 ml) and pentane (100 ml). The layers are separated and the aqueous layer is extracted with ether (2 × 50 ml). The combined organic phase is washed with aqueous sodium hydrogen carbonate solution (100 ml), dried with magnesium sulfate, concentrated, and flash distilled at reduced pressure (Kugelrohr apparatus) to give dienone **4a**; yield: 1.23 g (96%); b.p. (redistillation in a short-path apparatus) 102–104 °C/1.1 torr (Lit.[2a], b.p. 81–82 °C/0.1 torr); product crystallizes on standing, m.p. 86–88 °C.

Analysis by G.L.C. (20′ × 1/8″ OV-210 column, 180 °C) indicates the product to be 97% pure with only a trace of starting material present.

Characterization is accomplished as the *p*-toluenesulfonylhydrazone (Table), formed by *briefly warming* (~10–15 min) the dienone (1 mmol) and *p*-toluenesulfonyl hydrazine (1.1 mol) in ethanol (1 ml) followed by recrystallization from ethanol to obtain the analytical sample (Table).

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[1] (a) For a review of spiro[4.5]decane natural products see, J. A. Marshall, S. F. Brady, N. H. Andersen, *Fortschr. Chem. Org. Naturst.* **31**, 283 (1974).
(b) The classic case of such an offending rearrangement obscured the correct structure determination of β-vetivone for some time, see J. A. Marshall, S. F. Brady, *J. Org. Chem.* **35**, 4068 (1970) and cited references.

[2] (a) V. V. Kane, *Synth. Commun.* **6**, 237 (1976).
(b) A. B. Turner, H. J. Ringold, *J. Chem. Soc.* [C] **1967**, 1720.
(c) D. H. R. Barton, D. J. Lester, S. V. Ley, *J. Chem. Soc. Chem. Commun.* **1977**, 445.
D. H. R. Barton et al., *J. Chem. Soc. Perkin Trans. 1* **1977**, 567.
(d) V. B. Bierling, K. Kirschke, H. Oberender, *J. Prakt. Chem.* **314**, 170 (1972).

Table. Dehydrogenation of Enones **1** Via Organoselenium Reagents

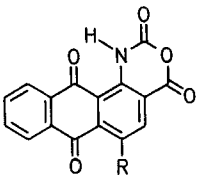
Product[a]	R^1	R^2	Yield [%][b]	b.p. [°C]/torr or m.p. [°C]	^{1}H-N.M.R. ($CDCl_3$) δ [ppm]		*p*-Tosylhydrazone of **4**	
					CH=CH–CO	CH=CH–CO	m.p. [°C]	Molecular formula[c]
4a	$-(CH_2)_5-$		96	102–104°/1.1; (Lit.[2a], 81–82°/0.1); m.p. 86–88°	6.29 (2H)	7.13 (2H)	170–172°	$C_{18}H_{22}N_2SO_2$ (330.5)
4b	$-(CH_2)_7-$		61	—[d]	6.20 (2H)	7.03 (2H)	173–176° (dec.)	$C_{20}H_{26}N_2SO_2$ (358.3)
4c	$-(CH_2)_2-CH=CH-CH_2-$		83	96–98°/1.1; m.p. 53–56°	6.10 (2H)	6.80 (2H)	172–174°	$C_{18}H_{20}N_2SO_2$ (328.4)
4d	$-(CH_2)_4-$		96	96–100°/1.1	6.26 (2H)	6.91 (2H)	145–147°	$C_{17}H_{20}N_2SO_2$ (316.4)
4e	$-(CH_2)_2-CH=CH-C(CH_3)_2-CH_2-$		80	—[d]	6.06 (2H)	6.75 (2H)	—[e]	—
4f	H_3C	H_3C	83	79–82°/7.2; (Lit.[6], 88–92°/15)	6.08 (2H)	6.85 (2H)	186–188°	$C_{15}H_{18}N_2SO_2$ (290.4)

[a] Products were >95% pure as determined by G.L.C. (20′ × 1/8″ OV-210 column).
[b] Yields of isolated and purified products.
[c] The microanalyses were in satisfactory agreement with the calculated values (C ±0.26, H ±0.28).
[d] Small scale reaction, not obtained.
[e] The lability of the product precluded characterization; spectral data was consistant with the dienone structure.

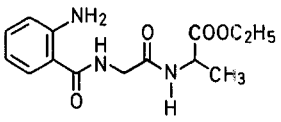
[3] (a) H. J. Reich, I. L. Reich, J. M. Renga, *J. Am. Chem. Soc.* **95**, 5813 (1973).
K. B. Sharpless, R. F. Lauer, A. Y. Teranishi, *J. Am. Chem. Soc.* **95**, 6137 (1973).
(b) For recent reviews of organoselenium chemistry including alkene formation, see, D. L. J. Clive, *Tetrahedron* **34**, 1049 (1978).
K. B. Sharpless et al., *Chem. Ser.* [A] **8**, 9 (1975).
H. J. Reich, *Acc. Chem. Res.* **12**, 22 (1979).
(c) K. C. Nicolaou, Z. Lysenko, *Tetrahedron Lett.* **1977**, 1257.
D. L. J. Clive et al., *Can. J. Chem.* **55**, 3894 (1977).
[4] The enones were prepared as previously described; N. R. Natale, R. O. Hutchins, *Org. Prep. Proced. Int.* **9**, 103 (1977).
[5] H. Plieninger, W. Gramlich, *Chem. Ber.* **111**, 1944 (1978).
[6] F. G. Bordwell, K. M. Wellman, *J. Org. Chem.* **28**, 2544 (1963).

0039-7881/80/1232-1037 $ 03.00

G. M. Coppola, *Synthesis* **1980** (7), 505–536;
The structures of compounds **43** (p. 511), **122** (p. 520), and **241** (p. 533) should be as shown below:



43



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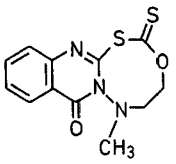
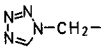


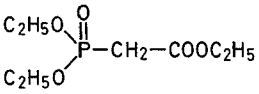
241

J. Diago-Meseguer, A. L. Palomo-Coll, J. R. Fernández-Lizarbe, A. Zugaza-Bilbao, *Synthesis* **1980** (7), 547–551;
The substitutent R^1 in Table 1 entries 2 and 20 and Table 2, entry 1 should be:



A more correct name for reagent **4** (as used in index) is **3,3'-(Chlorophosphinylidene)-bis[2-oxo-1,3-oxazolidine].**

J. Becher, *Synthesis* **1980** (8), 589–612;
The structure of compound **36** (p. 593) should be:



36

H. Paulsen, F. R. Heiker, J. Feldmann, K. Heyns, *Synthesis* **1980** (8), 636–638;
The correct name for reagent **1** is **3-methyl-2-selenoxo-2,3-dihydro-1,3-benzothiazole.**

G. Sosnovsky, J. A. Krogh, *Synthesis* **1980** (8), 654–656;
The first line of the text should read:
In 1978, Olah and Vankar reported[1] the conversion of

D. A. Walsh, *Synthesis* 1980 (9), 677–688;
The correct name for compound **39** (p. 680) is ***N'*-(2-Carboxyphenyl)-*N,N*-dimethylformamidine.**

M. A. Smoczkiewicz, J. Jasiczak, *Synthesis* **1980** (9), 739–740;
Compounds **2** should be named as **20,21-dioxo derivatives**; the name for compound **1a** (p. 740, Table 1) should be **21-hydroxy-3,20-dioxopregn-4-ene.**

Abstract 5878, *Synthesis* **1980** (9), 759;
The title should be: **Hydrofluorination, Halofluorination, and Nitrofluorination of Alkenes and Alkynes by Pyridinium Poly(Hydrogen Fluoride).**

Abstract 5885, *Synthesis* **1980** (9), 761;
The title should be: **Alkylation of *S*-Methyl 3-Oxoalkanethioates.**

T. Wagner-Jauregg, *Synthesis* **1980** (10), 769–798;
The name of compounds **552a** and **b** (p. 772) should be ***cis*-** and ***trans*-1-methyl-3-phenylindan.**
The heading for Table 2 (p. 784) should be:
Tabelle 2. Herstellung von 1-Arylacenaphthen-Derivaten durch Photocyclisierung von 1-(1-Arylethenyl)-naphthalin-Derivaten in Abwesenheit von Oxidationsmitteln[441].
The structures of the products in this Table should be of the type:

The first paragraph on p. 785 (right-hand side) should read:
Aus den konjugierten 1,2-Diiminen **667** und Phenyl-isocyanaten oder Benzoyl-isocyanat entstehen criss-cross-Addukte (**668**, Schema **2.2.1.-E**)[480,481].

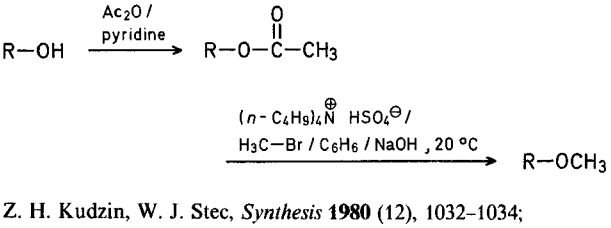
The last line on p. 794 should read:
und der Hydroxamsäuren[552] deutlich gesteigert[553].

Reference 441 (p. 796) should be:
[441] R. Lapougade, R. Koussini, H. Bouas-Laurent, *J. Am. Chem. Soc.* **99**, 7374 (1977).

H. Alper, D. E. Laycock, *Synthesis* **1980** (10), 799;
The last structure for R^1-R^2 in the Table should be:

T. Takajo, S. Kambe, *Synthesis* **1980** (10), 833–836;
Products designated as **4a,b,c,d** in Table 1 (p. 834) and Table 2 (p. 835) should be designated as **4a,b,f,g,** respectively.

P. Di Cesare, P. Duchaussoy, B. Gross, *Synthesis* **1980** (11), 953–954;
The first formula scheme (p. 954) should be:



Z. H. Kudzin, W. J. Stec, *Synthesis* **1980** (12), 1032–1034;
The heading for the first procedure (p. 1033) should be: **3-(Tris-[*t*-butoxy]silylthio)-propanal [3; R = (*t*-$C_4H_9O)_3Si$].**

R. E. Zipkin, N. R. Natale, I. M. Taffer, R. O. Hutchins, *Synthesis* **1980** (12), 1035–1036;
The substituents R^1-R^2 in the Table for product **4e** should be:
$-(CH_2)_2-C[=C(CH_3)_2]-CH_2-$

Abstract 5948, *Synthesis* **1980** (12), 1040;
Compounds **2** should be named **carboximidium dichlorides.**

Abstract 5963, *Synthesis* **1980** (12), 1045;
The title should be: **Acyl Fluorides, Chlorides, Bromides, and Iodides from Carboxylic Acids.**

Abstract 5973, *Synthesis* **1980** (12), 1047;
The title should be: **Acetoxylation-Arylselenylation of Alkenes.**