A Novel, Mercurial-Based Symmetrical Ketone Synthesis

Sir:

We report here a new and useful synthesis of symmetrical ketones by the reaction of organomercuric halides with dicobalt octacarbonyl. The advantages of this synthesis are that it proceeds rapidly at room temperature and atmospheric pressure and gives product in high yield, that it uses easily accessible starting materials,[1] that a simple, nonhydrolytic work-up can be used, and that it apparently is a general reaction, being applicable to the synthesis of diaryl and dialkyl ketones.

The reaction of phenylmercuric bromide (19 mmoles) and $Co_2(CO)_8$ (20 mmoles) is described as an example of the procedure used initially to identify the major reaction products. To the cobalt carbonyl in 30 ml of dry THF under nitrogen was added slowly a slurry of phenylmercuric bromide in 20 ml of THF. Moderate gas evolution began and the color of the solution changed from brown to deep green toward the end of the addition. The reaction mixture was stirred at room temperature for 2 hr. Volatiles were removed at reduced pressure. Extraction of the green-black residue with hexane, followed by cooling and concentration of the extracts, gave 5.84 g of red-brown solid, $Hg[Co(CO)_4]_2$, mp 80.5–82.5° (lit.[2] mp 81–82°). Complete evaporation of hexane and extraction of the resulting residue with aqueous methanol, followed by cooling of the extracts, gave another 2.0 g of this material. From the methanol solution there was obtained by evaporation to dryness and extraction with hexane 1.4 g (83%) of benzophenone, mp 46–47°, but brownish in color. Sublimation of the latter at 35–40° (0.05 mm) gave 1.25 g (73%, based on PhHgBr) of pure, white material, mp 46–47°, whose identity was proven by comparison (mixture melting point and infrared spectrum) with an authentic sample. The residue from the last hexane extraction was crystallized from wet acetone to give 2.1 g of $CoBr_2 \cdot 6H_2O$, which was identified by bromide ion precipitation and by means of its visible spectrum.

While this procedure demonstrated the formation of the products and allowed their isolation in good purity, it is unwieldy from the preparative point of view. Subsequent studies provided a simple work-up procedure (for the ketone formed) which is illustrated by the synthesis of 4,4′-difluorobenzophenone. A mixture of 5.4 mmoles each of *p*-fluorophenylmercuric bromide and $Co_2(CO)_8$ in 40 ml of THF was allowed to react at room temperature under nitrogen for 1 hr.[3] Tetrahydrofuran was removed at reduced pressure and the residue was extracted with 100 ml of hot benzene. To the red-orange benzene solution was added 5 g (19 mmoles) of triphenylphosphine. Gas evolution was followed by precipitation of $Hg[Co(CO)_3PPh_3]_2$, mp 205–210° dec.[4] Five milliliters of methyl iodide was added and the solution heated to precipitate unconverted triphenylphosphine as $Ph_3MeP^+I^-$. Filtration, removal of benzene from the filtrate, and sublimation of the residue gave 0.501 g (93%) of 4,4′-difluorobenzophenone, mp 103–105° (lit.[5a] mp 105–106°), whose $\nu_{C=O}$ (1663 cm^{-1}) agreed with that reported.[5b] This procedure served well in the preparation of benzophenone (80%), 4,4′-dimethylbenzophenone (86%), and 4,4′-dimethoxybenzophenone (84%). Reaction of ethylmercuric chloride with $Co_2(CO)_8$ gave pentanone-3 in 62% yield; a simple fractional distillation or glpc of the high-vacuum trap-to-trap distilled volatiles served in product isolation.

It is important to note the requirement of the 1:1 $Co_2(CO)_8$–RHgX stoichiometry in these reactions. If this ratio exceeds 1, then the reaction is not as clean as described and aldehydes are produced as well. The possible preparative significance of this observation is under investigation.

No experimental evidence relating to the mechanism of the RHgX–$Co_2(CO)_8$ reaction is available thus far. However, an approximate understanding of its course can be gained from results of previous workers. In donor solvents such as THF, dicobalt octacarbonyl is known to undergo disproportionation as shown in eq 1.[6] We suggest that nucleophilic attack at mercury

$$3Co_2(CO)_8 \xrightarrow{THF} 2Co(THF)_6^{2+} + 4Co(CO)_4^- + 8CO \qquad (1)$$

(a general, very facile reaction) follows eq 2 and that

$$RHgX + Co(CO_4)^- \longrightarrow RHgCo(CO)_4 + X^- \qquad (2)$$

subsequent reaction of $RHgCo(CO)_4$ with dicobalt octacarbonyl gives the observed $Hg[Co(CO)_4]_2$ and $RCo(CO)_4$ (eq 3).[7]

$$RHgCo(Co)_4 + Co_2(CO)_8 \longrightarrow RCo(CO)_4 + Hg[Co(CO)_4]_2 \qquad (3)$$

Rearrangement of organocobalt tetracarbonyls to acylcobalt carbonyls [$RCo(CO)_4 \rightarrow RC(O)Co(CO)_3$] is a characteristic reaction in organocobalt chemistry,[8] and the formation of ketones from alkylcobalt carbonyls or from $RCo(CO)_n + RC(O)Co(CO)_m$ reactions also has been reported.[9] At this time we merely wish to stress our belief that organocobalt carbonyls are intermediates in the RHgX–$Co_2(CO)_8$ reaction, but we must note that we do not know by what exact path they are formed. These reactions are somewhat reminiscent of the RLi + $Ni(CO)_4$,[10] RLi + $Fe(CO)_5$,[11] and PhMgBr + $CrCl_3$ + CO[12] reactions (in which ketones,

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[1] Dicobalt octacarbonyl is available from several commercial sources. Arylmercuric halides are easily prepared by mercuration of aromatic compounds and alkyl- and arylmercuric halides also can be prepared by reaction of mercuric halides with various alkylmetal reagents.

[2] S. V. Dighe and M. Orchin, *Inorg. Chem.*, **1**, 965 (1962); W. Hieber and H. Schulten, *Z. Anorg. Allgem. Chem.*, **232**, 17 (1937).

[3] Thin layer chromatography (20% benzene–cyclohexane; silica gel) indicated complete consumption of the arylmercuric bromide at this point.

[4] W. Hieber and R. Breu, *Chem. Ber.*, 90, 1259 (1957), indicated that this reaction removes $Hg[Co(CO)_4]_2$ from solution quantitatively.

[5] (a) W. Funasaka, T. Ando, K. Kondo, and S. Kodama, *Kûki Gosei Kagaku Kyôkai Shi*, 17, 717 (1959); *Chem. Abstr.*, **55**, 2248 (1961); (b) E. J. Moriconi, W. F. O'Connor, and W. F. Forbes, *J. Am. Chem. Soc.*, **84**, 3928 (1962).

[6] E. W. Abel, *Quart. Rev.* (London), **17**, 133 (1963).

[7] One could picture $Co_2(CO)_8$ reacting as $[THF \cdot Co(CO)_4]^+[Co(CO)_4]^-$.

[8] Many references could be cited. The following two illustrate this point: (a) R. F. Heck and D. S. Breslow, *J. Am. Chem. Soc.*, **83**, 4023 (1961); (b) *ibid.*, **84**, 2499 (1962).

[9] (a) W. Hieber, O. Vohler, and G. Braun, *Z. Naturforsch.*, **13b**, 192 (1958); (b) W. Hieber, W. Beck, and E. Lindner, *ibid.*, **16b**, 229 (1961); (c) J. A. Bertrand, C. L. Aldridge, S. Husebye, and H. B. Jonassen, *J. Org. Chem.*, **29**, 790 (1964).

[10] (a) S. K. Myeong, Y. Sawa, M. Ryang, and S. Tsutsumi, *Bull. Chem. Soc. Japan*, **38**, 330 (1965); (b) *J. Organometal. Chem.* (Amsterdam), **5**, 305 (1966).

[11] M. Ryang, I. Rhee, and S. Tsutsumi, *Bull. Chem. Soc. Japan*, **37**, 341 (1964).

[12] M. Ryang, K. Yoshida, and S. Tsutsumi, *Technol. Repl. Osaka Univ.*, **16**, 205 (1966).

in addition to other products, are formed) studied in recent years by Japanese workers. However, the RHgX–$CO_2(CO)_8$ reaction differs considerably from these reactions which involve more reactive organometallic reagents in over-all mechanism and in that it proceeds cleanly and does not give a mixture of products when carried out properly.

Our studies of this reaction and its extensions, with the aim of defining more fully its scope and its mechanism, are continuing.

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[13] National Institutes of Health Predoctoral Fellow.

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Additions and Corrections

Halomethyl–Metal Compounds. XII. The Action of Sodium Iodide on Phenyl(trihalomethyl)mercury Compounds. A New Method of Dihalocarbene Generation. [*J. Am. Chem. Soc.*, **89**, 959 (1967)]. By DIETMAR SEYFERTH, MICHAEL E. GORDON, JEFFREY YICK-PUI MUI, and JAMES M. BURLITCH, Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

In Table I, the last entry in the third column [Product (yield, %)] should read: 2,2-Dichlorocyclopropyl acetate (14) and $CH_3CH(CCl_3)O_2CCH_3$ (7).

A Reinterpretation of the Nuclear Magnetic Resonance Spectrum of Cyclobutene [*J. Am. Chem. Soc.*, **89**, 2047 (1967)]. By E. ALEXANDER HILL, Department of Chemistry, University of Wisconsin—Milwaukee, Milwaukee, Wisconsin 53201, and JOHN D. ROBERTS, Gates and Crellin Laboratories of Chemistry, California Institute of Technology, Pasadena, California 91109.

On page 2049, the legend to Figure 1, b and c, should read: b, vinyl hydrogens of a cyclobutene mixture of -2,2,3-d_3 and -1,3,3-d_3; c, methylene hydrogens of the same mixture as in b.

Inversion Barriers of Pyramidal (XY_3) and Related Planar (=XY) Species. [*J. Am. Chem. Soc.*, **89**, 3396 (1967)]. By G. W. KOEPPL, D. S. SAGATYS, G. S. KRISHNAMURTHY, and SIDNEY I. MILLER. Department of Chemistry, Illinois Institute of Technology, Chicago, Illinois 60616.

On page 3400, column 2, line 14 add the following sentence: Configurationally stable rather than optically active phosphites are known (ref 20f). On page 3401, column 2, line 8 [6.1.0] should read [4.1.0]. On page 3402, in the Isotopes Effects section: deuterium ions should read deuteronium ions. On page 3404, column 1 delete the last paragraph. In Table I, for $SnCl_3^-$, $\nu_1 = 297$; for PT_3, $k_\delta/l^2 = 3.0825$; for IO_3^-, $\nu_2 = 390$. In Tables I, II, and III, delete all entries for NF_3, NCl_3, and PI_3. In Table III, delete the last entry for =NF.

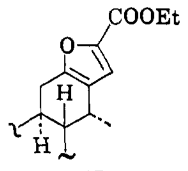
We now have a program in which any set (or sets) of force constants can be introduced into the calculation to replace those generated from the input data. By this technique, we generated V_i (kcal/mole) as follows: NF_3, 56–59; PF_3, 29–66; PI_3, 43; AsF_3, 36–41; AsI_3, 25–40. Five or six trials with arbitrary force constants for PF_3 gave equally arbitrary values of V_i = 29–66 kcal/mole.

The Synthesis of 3-(2′-Deoxy-D-ribofuranosyl)adenine. Application of a New Protecting Group, Pivaloyloxymethyl (Pom) [*J. Am. Chem. Soc.*, **89**, 5439 (1967)]. By MALCOLM RASMUSSEN and NELSON J. LEONARD. Department of Chemistry and Chemical Engineering, University of Illinois, Urbana, Illinois 61801.

On pages 5439, 5441, 5442, and 5444, the preferred name for **2** is 3,5-di-O-(*p*-chlorobenzoyl)-2-deoxy-D-ribofuranosyl chloride.

Total Synthesis of Racemic Methyl Vinhaticoate. [*J. Am. Chem. Soc.*, **89**, 5497 (1967)]. By T. A. SPENCER, R. M. VILLARICA, D. L. STORM, T. D. WEAVER, R. J. FRIARY, J. POSLER, and P. R. SHAFER. Department of Chemistry, Dartmouth College, Hanover, New Hampshire 03755.

On page 5498 formulas **17** and **13** should appear as shown here, rather than as published.



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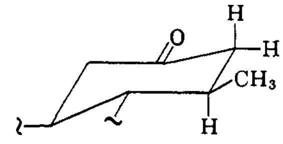

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One Electron Transfer Oxidation of 7,12-Dimethylbenz[*a*]anthracene, a Model for the Metabolic Activation of Carcinogenic Hydrocarbons [*J. Am. Chem. Soc.*, **89**, 5508 (1967)]. By JOSEF FRIED and DOROTHY E. SCHUMM. Ben May Laboratory for Cancer Research and Department of Chemistry and Biochemistry, University of Chicago, Chicago, Illinois 60637.