Experimental

Melting points were determined on calibrated hot stages.

1-(Cyclohexanecarboxamido)cyclohexanecarbonitrile (LXIII).—Cyclohexanecarbonyl chloride[6] (44 g., 0.300 mole) was added dropwise to a solution of 1-aminocyclohexanecarbonitrile (32 g., 0.258 mole) in pyridine (50 ml.) and benzene (120 ml.). Then the resulting solution was placed in a large water bath initially at 80°, and kept for 12 hr., during which the bath and reaction solution gradually cooled to room temperature and a white solid precipitated. Chloroform (300 ml.) and water (300 ml.) were then added, causing the entire mixture to dissolve. The chloroform layer was washed successively with 5% hydrochloric acid, 5% aqueous sodium bicarbonate solution, and water, and then dried over magnesium sulfate and evaporated, leaving a pasty solid. Crystallization from ethanol–water gave white plates (54.2 g., 90%), m.p. 161.5–164.5°. Three recrystallizations from ethanol–water yielded glistening white plates, m.p. 163–164°; ν_{NH} 3250 s, 3030 w, 1538 s, $\nu_{C\equiv N}$ 2230 vw, $\nu_{C=O}$ 1650 s, cm.$^{-1}$ (Nujol).

Anal. Calcd. for $C_{14}H_{22}N_2O$ (234.33): C, 71.75; H, 9.46; N, 11.96. Found: C, 71.89; H, 9.39; N, 11.90.[7]

Attempted Cyclization of LXIII with Base: Cleavage to Cyclohexanecarboxamide. A. With Sodamide.—Compound LXIII (2.1 g., 0.0090 mole) and sodamide (0.2 g., 0.0051 mole) were heated together to 180° for 1 hr. At about 150° a violent evolution of gas occurred. After the mixture had cooled, it was dissolved in ethanol and the solution diluted with water and made acid with dilute hydrochloric acid. White needles (0.297 g., 26%) precipitated, which had an infrared spectrum (Nujol) identical with that of authentic cyclohexanecarboxamide. Recrystallization from ethanol–water, sublimation under reduced pressure, and two additional recrystallizations from chloroform–light petroleum ether (b.p. 60–68°) yielded **cyclohexanecarboxamide** as shiny white plates, m.p. 190–191°; lit.[8] m.p. 184°, lit.[9] 185–186°; ν_{NH} 3340 s, 3160 s, $\nu_{C=O}$ 1635 s cm.$^{-1}$ (Nujol).

Anal. Calcd. for $C_7H_{13}NO$ (127.18): C, 66.10; H, 10.30; N, 11.01. Found: C, 66.18; H, 10.34; N, 9.75.

B. With Sodium Hydride.—Compound LXIII (2.10 g., 0.00895 mole) and solid sodium hydride (0.3 g., 0.012 mole) were refluxed in benzene (30 ml.) for 20 hr. Then absolute ethanol (1 ml.), *t*-butyl alcohol (1 ml.), and sodium (0.03 g., 0.0013 g.-atom) were added, and the solution was refluxed for 4 hr. more. Evaporation of the solvents left an orange oily residue, which was partitioned between chloroform and dilute hydrochloric acid. The chloroform layer was concentrated, and then diluted with light petroleum ether (b.p. 60–68°). The solid which precipitated was sublimed under reduced pressure, yielding **cyclohexanecarboxamide** (0.103 g., 9%), m.p. 189–190°, having an infrared spectrum (Nujol) identical with that of an authentic sample and with that of the sample prepared with sodamide (part A.).

Ethyl Cyclohexanone-2-carboxylate.—The compound was obtained[10] in 59% yield (from cyclohexanone) as a colorless liquid, $n^{28}D$ 1.4762; lit.[10] 59–62%, $n^{25}D$ 1.476–1.479; $\nu_{C=O}$ 1731 s, 1710 s, 1650 vs, $\nu_{C=C}$ 1618 vs cm.$^{-1}$ on the liquid.

Ethylene Ketal of Ethyl Cyclohexanone-2-carboxylate. Ethyl 1,4-Dioxaspiro[4.5]decane-6-carboxylate (LXV).—*p*-Toluenesulfonic acid (0.2 g.) was added to a solution of ethyl cyclohexanone-2-carboxylate (34.0 g., 0.200 mole) and ethylene glycol (16.7 g., 0.269 mole) in benzene (100 ml.), and the solution was refluxed for 3 hr., during which time water (4.5 ml., 124%) was collected in a Dean–Stark water trap. The benzene solution was then washed with aqueous sodium bicarbonate solution, dried over sodium bicarbonate, and distilled, giving a colorless liquid (39.3 g., 92%), b.p. 95–104° (1 mm.), $n^{30}D$ 1.4634. Redistillation through a 10-cm. spiral wire column yielded a colorless liquid (35.7 g., 83%), $n^{28}D$ 1.4632, $\nu_{C=O}$ 1733 s cm.$^{-1}$ on the liquid.

Anal. Calcd. for $C_{11}H_{18}O_4$ (214.25): C, 61.66; H, 8.47. Found: C, 61.17; H, 8.60.

Bis(1-cyanocyclohexyl)amine (LXVI).—1-Aminocyclohexanecarbonitrile (20.0 g., 0.161 mole; prepared[2] in 87% yield from ammonia and cyclohexanone cyanohydrin) was kept at room temperature for 40 hr. and at 90° for 20 hr. The now reddish liquid was cooled in ice, causing crystallization to a mass of yellowish crystals. After 1 hr. a solution (20 ml.) of 1:1 ether–light petroleum ether (b.p. 60–68°) was added, leaving undissolved white crystals (4.04 g., 22%), m.p. 135–136°. Two recrystallizations from chloroform–light petroleum ether yielded white plates, m.p. 137–138°, lit.[4] m.p. 136°; ν_{NH} 3310 ms, $\nu_{C\equiv N}$ 2200 w cm.$^{-1}$ (Nujol).

Anal. Calcd. for $C_{14}H_{21}N_3$ (231.33): C, 72.68; H, 9.15; N, 18.17. Found: C, 73.07; H, 9.23; N, 18.42.

7,14-Diazadispiro[5.1.5.2]pentadecan-15-one (LXVII).—1-Aminocyclohexanecarbonitrile[2] (21.0 g., 0.169 mole) was added to a solution of sodium ethoxide prepared by adding sodium (2.8 g., 0.122 g.-atom) to 98.4% (by weight) ethanol (80 ml.). White needles, which began to form after a few minutes at room temperature, had filled the solution within 2 hr. After a total of 21 hr. the needles were filtered, and three more crops were collected, giving a total of 17.66 g. (94%), m.p. 219–222°, having an infrared spectrum identical with that of the analytical sample. Two recrystallizations from chloroform–light petroleum ether (b.p. 60–68°) yielded the analytical sample as white needles, m.p. 219°; ν_{NH} 3300 w, 3220 m, 3020 w, $\nu_{C=O}$ 1687 s cm.$^{-1}$ (Nujol).

Anal. Calcd. for $C_{13}H_{22}N_2O$ (222.32): C, 70.23; H, 9.97; N, 12.60. Found: C, 70.14; H 10.04; ,N, 12.65.

---

[6] A. C. Cope and E. Ciganek, *Org. Syn.*, **39**, 19 (1959).

[7] The compound, although pure, gave erratic nitrogen analyses. Two other analyses on a single sample of m.p. 163–164° gave N, 13.42, 10.53.

[8] (a) O. Aschan, *Ann.*, **271**, 231 (1892); (b) J. S. Lumsden, *J. Chem. Soc.*, **87**, 90 (1905).

[9] W. Markownikoff, *Ber.*, **25**, 3355 (1892).

[10] H. R. Snyder, L. A. Brooks, and S. H. Shapiro, "Organic Syntheses," Coll Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 531.

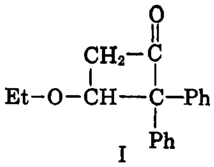
A New Type of Reaction of Phenylmagnesium Bromide with a Sterically Hindered Cyclobutanone

RAYMOND D. KIMBROUGH, JR.

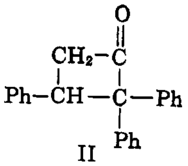
School of Chemistry, Georgia Institute of Technology, Atlanta 32, Georgia

Received July 31, 1963

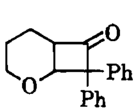
Unhindered cyclobutanones react normally with carbonyl reagents and give the expected phenylhydrazones, semicarbazones, and like derivatives. Certain sterically hindered cyclobutanones, such as the cycloaddition products of diphenylketene with ethyl vinyl ether,[1] I, with styrene,[2] II, and with dihydropyran,[1] III, do not react with phenylhydrazine or semicarbazide, presumably because the two phenyl groups hinder the carbonyl carbon and prevent any reaction from occurring at this position.[1,2]



I



II



III

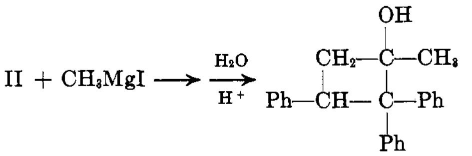
Such sterically hindered cyclobutanones are known to undergo two types of reaction with Grignard reagents. A methylmagnesium halide gives a normal reaction,[3] while the bulkier phenylmagnesium halide gives a ring-opening reaction.[3] Here the phenylmagnesium bromide acts as a base and removes the weakly acidic α-hydrogen to produce the cyclobutanone enolate which undergoes ring opening to give a more stable enolate.

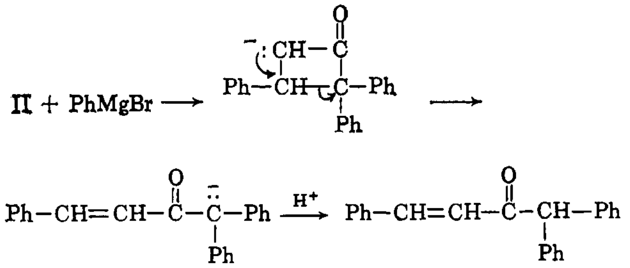
---

[1] C. D. Hurd and R. D. Kimbrough, *J. Am. Chem. Soc.*, **82**, 1373 (1960).

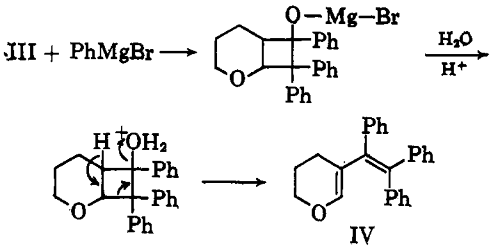
[2] H. Staudinger and E. Suter, *Ber.*, **53**, 1092 (1920).

[3] H. Staudinger and A. Rheiner, *Helv. Chim. Acta*, **7**, 8 (1924).



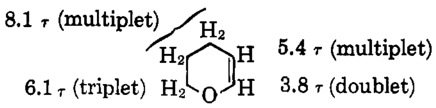


Compound III has been found to undergo a third type of reaction with phenylmagnesium bromide, the product being a yellow crystalline solid which shows no carbonyl absorption in the infrared spectrum. The elementary analysis indicates that the product came from III by the addition of benzene at the carbonyl group followed by elimination of water. The following reaction pathway is proposed.

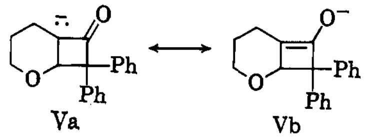


The yellow color of product IV is explained by the triphenylbutadiene system which is conjugated to an ether oxygen. The product gives benzophenone on oxidation with chromium trioxide in acetic acid, indicating that the product contains a diphenylmethylene group. The proposed reaction pathway also explains why the reaction mixture did not become deep yellow until it was acidified.

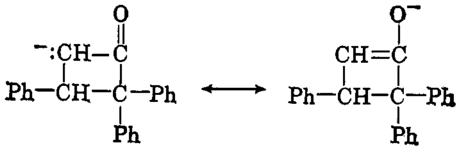
Conclusive evidence that the structure of the yellow product is IV is provided by the n.m.r. spectrum of the substance. A solution of the material in carbon disulfide exhibited signals at 2.8 (multiplet), 3.6 (singlet), 5.9 (triplet), 7.1 (triplet), and 7.9 τ (multiplet), with relative intensities of 15:1:2:2:2. The multiplet at 2.8 τ is due to the fifteen aromatic protons. The rest of the spectrum compares well with that of dihydropyran.[4] The singlet at 3.6 is due to the olefinic hydrogen next to the ether oxygen, the triplet at 5.9 to the methylene next to the ether oxygen, the triplet at 7.1 to the allylic methylene, and the multiplet at 7.9 τ to the remaining aliphatic methylene. The splitting of the signals at 5.9 and 7.1 τ into triplets is caused by the two adjacent hydrogens of the middle methylene group.



That phenylmagnesium bromide does not abstract a proton from III, comparable to the proton abstracted from II, suggests that III is less acidic than II. This greater acidity of II could be caused by the inductive effect of the 3-phenyl group in II, which is lacking in III. Another explanation is that the enolate V from III should be less stable (more strained) than the enolate VI from II. Although structure Vb does not violate Bredt's rule, it is strained and should be less stable than the enolate of a cyclobutanone which was not fused to another ring, such as VI.



Va Vb



VI

Experimental

Analyses were by Galbraith Laboratories, Inc., Knoxville, Tenn. Melting points are uncorrected. Infrared spectra were measured on a Perkin-Elmer Infracord. N.m.r. spectra were measured with a Varian A-60 spectrometer at 60 Mc. using tetramethylsilane as an external standard.

5-Triphenylvinyl-2,3-dihydro-4*H*-pyran (IV).—The ether solution of phenylmagnesium bromide, from 40 ml. of bromobenzene, 20 g. of magnesium (a 2 *M* excess), and 200 ml. of ether, was decanted from the unchanged magnesium. A solution of 8.0 g. of the adduct of diphenylketene and dihydropyran,[1] III, in 100 ml. of benzene, diluted with 100 ml. of ether, was added dropwise with stirring and cooling in ice during 15 min. The reaction mixture was kept at room temperature for a day. To the stirred and cooled reaction mixture was added dropwise 60 ml. of water followed by 60 ml. of concentrated HCl. The addition took 30 min. The stirring was continued until all of the solid had dissolved. The deep red-orange organic layer was separated and dried over $MgSO_4$. The solvents were removed on a rotary evaporator in a water bath at 50°, first at 15 mm. and then at 1 mm. To the dark semisolid residue was added 60 ml. of ethyl acetate. A yellow solid formed immediately. After 15 min. it was collected on a filter, washed twice with 5 ml. of ethyl acetate, and dried; yield, 4.4 g. (46%); m.p. 189–193°. This material was recrystallized from 150 ml. of ethyl acetate to yield 2.0 g., m.p. 193–195°. Another 1.1 g. could be recovered from the mother liquor. Another recrystallization from ethyl acetate raised the melting point to 195–196°. The infrared ($CHCl_3$) showed 6.25, 6.70, 6.93, 7.88, 8.52, 9.13, 9.39, 9.71, 10.02 μ.

Anal. Calcd. for $C_{25}H_{22}O$: C, 88.7; H, 6.5. Found: C, 88.3; H, 6.5.

Oxidation of IV.—To a boiling solution of 0.40 g. of IV in 10 ml. of acetic acid was added 1.0 g. of chromium trioxide over a 5-min. period. The heat of reaction was sufficient to keep the reaction mixture boiling without additional heating. The reaction mixture was diluted with 40 ml. of water and made basic with 40% NaOH. The mixture was distilled and 30 ml. of distillate was collected. The insoluble oil crystallized immediately on seeding with benzophenone. The yield of benzophenone was 0.11 g. (52%), m.p. 44–46°. A mixture of this material with benzophenone melted 45–47°.

The low yield of benzophenone is partly due to the fact that benzophenone is oxidized slowly under these reaction conditions.[5]

---

(4) R. M. Silverstein and G. C. Bassler, "Spectrometric Identification of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1963, p. 135.

(5) W. Langenbeck and H. Langenbeck, *Ber.*, **61**, 938 (1928).