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of Reliable Methods
for the Preparation
of Organic Compounds

Working with Hazardous Chemicals

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September 2014: The paragraphs above replace the section "Handling and Disposal of Hazardous Chemicals" in the originally published version of this article. The statements above do not supersede any specific hazard caution notes and safety instructions included in the procedure.

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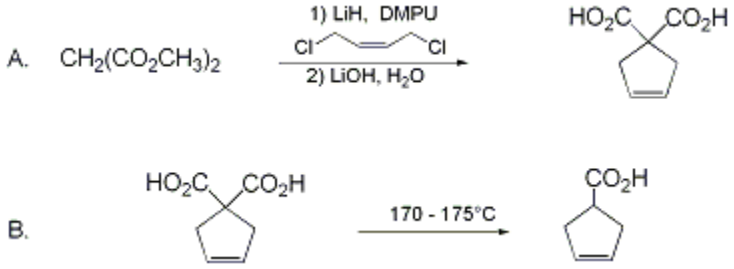
3-CYCLOPENTENE-1-CARBOXYLIC ACID



Submitted by Jean-Pierre Deprés and Andrew E. Greene[1] .
Checked by Tammy J. Clark and Robert K. Boeckman, Jr..

1. Procedure

Caution! These transformations should be carried out in an efficient hood.

A. 3-Cyclopentene-1,1-dicarboxylic acid . A dry, 1-L, two-necked, round-bottomed flask (Note 1), equipped with a Teflon-covered magnetic stirring bar, is charged under a current of nitrogen with 33.0 g (0.250 mol) of dimethyl malonate , 50 mL of dry N,N'-dimethylpropyleneurea, DMPU, and 450 mL of dry tetrahydrofuran, THF (Note 2). The resulting solution is cooled by means of an ice bath and treated with 5.00 g (0.629 mol) of lithium hydride powder in one portion (Note 3). The nitrogen flow is discontinued, and the flask is capped with rubber septa and connected to a Nujol-filled bubbler by means of a syringe needle. After 15 min, the cooling bath is removed and stirring is continued until hydrogen evolution is complete (ca. 2 hr), whereupon 28.4 mL (0.269 mol) of cis-1,4-dichloro-2-butene (Note 4) is rapidly added by syringe. The mixture is heated by means of an oil bath at 40-45°C for 24 hr (Note 5). After the mixture is cooled to 20°C, 50 mL of water is added dropwise followed by 31.5 g (0.750 mol) of solid lithium hydroxide monohydrate . After the reaction mixture is stirred at 20°C for an additional 24 hr, it is treated with 350 mL of water, stirred for 10 min, and then transferred to a 2-L separatory funnel. Neutral material is removed by extraction with five 500-mL portions of ethyl acetate , each of which is back-washed with 30 mL of aqueous saturated sodium chloride solution. The combined aqueous phases are then acidified with 160 mL of 6 N hydrochloric acid , and extracted three times with 500-mL portions of ethyl acetate . The ethyl acetate extracts are combined, washed three times with 100 mL of 3 N hydrochloric acid and twice with 50 mL of aqueous saturated sodium chloride solution, dried over sodium sulfate , filtered, and concentrated by rotary evaporation. After removal of traces of solvent under high vacuum (1 hr at 0.1 mm), 35.8 g (92%) of 3-cyclopentene-1,1-dicarboxylic acid is obtained as an off-white solid, mp 163-165°C (Note 6).

B. 3-Cyclopentene-1-carboxylic acid . A 250-mL, one-necked, round-bottomed flask is charged with 35.8 g of 3-cyclopentene-1,1-dicarboxylic acid and then fitted with a reflux condenser capped with a rubber septum and connected to a Nujol-filled bubbler by means of a syringe needle. The contents of the flask are heated in an oil bath at 170-175°C until carbon dioxide evolution is complete (ca. 2 hr) and then allowed to cool to room temperature. The resulting oil is transferred to a 50-mL flask and vacuum distilled without fractionation to provide 23.0 g (89% or 82% overall from dimethyl malonate) of 3-cyclopentene-1-carboxylic acid as a clear, colorless oil, bp 88°C (2 mm) (Note 7).

2. Notes

1. All glassware was oven-dried and allowed to cool in a desiccator before use.
2. Dimethyl malonate (98%) was obtained from Fluka Chemical Corp. , and DMPU was purchased from Aldrich Chemical Company, Inc. DMPU was distilled from calcium hydride under reduced pressure and tetrahydrofuran was distilled from the sodium ketyl of benzophenone prior to use. The

checkers employed dimethyl malonate obtained from Aldrich Chemical Company, Inc.
3. Lithium hydride powder was obtained from Acros Organics . The checkers obtained lithium hydride from Aldrich Chemical Company, Inc.
4. cis-1,4-Dichloro-2-butene was either purchased from Aldrich Chemical Company, Inc. or prepared[2] from cis-2-butene-1,4-diol (Fluka Chemical Corp.). The checkers used cis-1,4-dichloro-2-butene obtained from Aldrich Chemical Company, Inc.
5. The submitters report that dimethyl 3-cyclopentene-1,1-dicarboxylate (with <1% of the vinyl isomer) [2,3] can be isolated at this stage in 92% yield and then transformed to methyl 3-cyclopentene-1-carboxylate [4] with lithium chloride in wet dimethyl sulfoxide (DMSO)[5] in 85% yield.
6. The checkers obtained a yield of 99% for the diacid, mp 160-163°C. Melting points of 164-169°C,[2] 170-172°C,[2] and 162-165°C [3] have been reported for this compound. The diacid has the following spectral properties: IR (Nujol) cm^{-1}: 3067, 1698, 1623 ; ^1H NMR [$CDCl_3$-CD_3COCD_3 (8:2), 300 MHz] δ: 3.08 [s(br), 4 H], 5.63 [s(br), 2 H], 10.90 [s(br), 2 H] ; ^{13}C NMR [$CDCl_3$-CD_3COCD_3 (8:2), 75 MHz] δ: 46.5, 64.3, 133.1, 178.5 .
7. The checkers obtained yields of 91-93% for the acid, bp 81-83°C (1.7 mm). Distillation temperatures of 83-84°C (2 mm)[2]and 70°C (1 mm)[3] have been reported for this compound. The acid has the following spectral properties: IR cm^{-1}: 3060, 1707, 1623 ; ^1H NMR ($CDCl_3$, 300 MHz) δ: 2.70 (m, 4 H), 3.12-3.25 (m, 1 H), 5.68 [s(br), 2 H], 11.96 [s(br), 1 H] ; ^{13}C NMR ($CDCl_3$, 75 MHz) δ: 36.2, 41.5, 129.2, 182.5 .

Waste Disposal Information

All toxic materials were disposed of in accordance with "Prudent Practices in the Laboratory"; National Academy Press; Washington, DC, 1995.

3. Discussion

The preparation described here of 3-cyclopentene-1-carboxylic acid from dimethyl malonate and cis-1,4-dichloro-2-butene is an optimized version of a method reported earlier[3] for obtaining this often used and versatile building block.[6] The procedure is simple and efficient and requires only standard laboratory equipment. 3-Cyclopentene-1-carboxylic acid has previously been prepared through reaction of diethyl malonate with cis-1,4-dichloro(or dibromo)-2-butene in the presence of ethanolic sodium ethoxide, followed by hydrolysis of the isolated diethyl 3-cyclopentene-1,1-dicarboxylate intermediate, fractional recrystallization of the resultant diacid to remove the unwanted vinylcyclopropyl isomer, and finally decarboxylation.[2,7] Alternatively, this compound can be obtained from the vinylcyclopropyl isomer (prepared from diethyl malonate and trans-1,4-dichloro-2-butene)[8] or from cyclopentadiene [9] or cyclopentene.[10] In comparison with the present procedure, however, all these methods suffer from poor selectivity, low yields, length, or need of special equipment or reagents, if not a combination of these drawbacks.

References and Notes

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Appendix
Chemical Abstracts Nomenclature (Collective Index Number); (Registry Number)

3-Cyclopentene-1-carboxylic acid (8,9); (7686-77-3)

3-Cyclopentene-1,1-dicarboxylic acid (11); (88326-51-6)

Dimethyl malonate:
Malonic acid, dimethyl ester (8);
Propanedioic acid, dimethyl ester (9); (108-59-8)

N,N'-Dimethylpropyleneurea [DMPU]:
2(1H)-Pyrimidinone, tetrahydro-1,3-dimethyl- (8,9); (7226-23-5)

Lithium hydride (8,9); (7580-67-8)

cis-1,4-Dichlorobut-2-ene:
2-Butene, 1,4-dichloro-, (Z)- (8,9); (1476-11-5)

Lithium hydroxide monohydrate (8);
Lithium hydroxide, monohydrate (9); (1310-66-3)