

trituated with absolute ethanol and filtered. The crude thiazolone was crystallized from a mixture of absolute ethanol and benzene to give 15.4 g. (58% yield) of I, m.p. 130°, lit.,<sup>3-5</sup> 129.5–130°, 132–133°.<sup>6</sup>

**Reaction of I with Benzene under Friedel-Crafts Conditions.**—In a 500-ml. round-bottomed flask, fitted with a mechanical stirrer, dropping funnel, and reflux condenser, was placed 6.4 g. (0.048 mole) of anhydrous aluminum chloride in 65 ml. of dry thiophene-free benzene. The mixture was cooled to 10° and stirred for 1 hr. in a nitrogen atmosphere. To this solution was added 3.18 g. (0.012 mole) of 2-phenyl-4-benzylidene-5(4*H*)-thiazolone (I) in 60 ml. of dry benzene and the temperature maintained at 10–20° during the addition. The mixture turned deep red. When all of the thiazolone had been added, the mixture was stirred for an additional 3 hr. at room temperature. The complex was decomposed with 125 ml. of dilute (1:15) hydrochloric acid to form two clear layers. The benzene layer was separated, the aqueous layer extracted with benzene and the combined benzene layers washed with dilute hydrochloric acid and then with water until neutral to litmus. Benzene was removed under reduced pressure to give an oil which was trituated with absolute ethanol. The product was crystallized from an ethanol-benzene mixture to give 3.02 g. of pale yellow crystals (II), m.p. 109–110°.

*Anal.* Calcd. for C<sub>22</sub>H<sub>17</sub>NOS: C, 73.96; H, 4.95. Found: C, 73.91; H, 5.06.

**Reaction of I with Phenylmagnesium Bromide.**—To 0.45 g. (0.019 g.-atom) of magnesium turnings in 30 ml. of anhydrous ether in a nitrogen atmosphere was added dropwise 2 ml. of bromobenzene (0.019 mole) dissolved in 25 ml. of ether. After the reaction had subsided, the mixture was heated under reflux for 0.5 hr. I (1.59 g.) suspended in 65 ml. of ether was added over a 1-hr. period. The mixture was heated under reflux for an additional 2 hr. and then decomposed with a saturated solution of ammonium chloride. The ether layer was removed, repeatedly washed with water, and dried over anhydrous magnesium sulfate. Ether was removed by evaporation on a water bath. The residual oil was trituated with absolute ethanol when a pale yellow solid separated. It was recrystallized from an ethanol-benzene mixture to give 3.3 g. (70% yield) of a pale yellow solid, m.p. 109°, mixture m.p., no depression.

**2-Phenyl-4-benzhydryl-5-thiazolone (II).**—A mixture of 2.5 g. of 2-phenyl-4-benzhydryl-5-oxazolone, 2 g. of thioacetic acid, and 1 drop of triethylamine was heated at 100° for 18 hr. After cooling, the residue was trituated with absolute ethanol, filtered, and crystallized from an ethanol-benzene mixture to give 1.5 g. of compound II. The melting point and infrared spectrum of this material were identical with those of compound II described previously.

**Reaction of II with Aniline.**—2-Phenyl-4-benzhydryl-5-thiazolone (0.69 g.), 0.28 ml. of aniline and a crystal of aniline hydrochloride were heated under reflux for 3 hr. in 20 ml. of dry benzene. The mixture was cooled and the anilide which separated was crystallized from absolute ethanol, m.p. 244°.

*Anal.* Calcd. for C<sub>25</sub>H<sub>24</sub>N<sub>2</sub>OS: C, 74.33; H, 5.30. Found: C, 74.22; H, 5.47.

**Alkaline Hydrolysis of II.**—Two grams of thiazolone was heated under reflux in 100 ml. of 2*N* ethanolic sodium hydroxide for 12 hr. The mixture was cooled and acidified with dilute hydrochloric acid. 2-Thiobenzamido-3,3-diphenylpropionic acid separated and was crystallized from benzene, m.p. 186°.

*Anal.* Calcd. for C<sub>21</sub>H<sub>19</sub>NO<sub>2</sub>S: C, 73.13; H, 5.26. Found: C, 73.20; H, 5.16.

**Acid Hydrolysis.**—2-Thiobenzamido-3,3-diphenylpropionic acid (0.5 g.) was heated under reflux with 15 ml. of a 2:1 mixture of acetic acid and 48% hydrobromic acid. Excess acid was distilled and the residue dissolved in water and extracted with ether. The aqueous layer was concentrated to give 3,3-diphenylalanine hydrobromide, m.p. 204°.<sup>16</sup>

**Reaction of I with Phenyllithium.**—To 0.27 g. (0.0375 g.-atom) of lithium, suspended in 50 ml. of dry ether was added several milliliters of a solution of 2 ml. (0.019 mole) of bromobenzene in 10 ml. of ether.

The mixture was heated under reflux until reaction began and then the remainder of the bromobenzene solution was added at intervals so as to ensure gentle reflux. I (1.59 g.), in 60 ml. of ether, was added in portions during a 15-min. period and the mixture was heated under reflux for 0.5 hr. The reaction mixture was hydrolyzed with a saturated solution of ammonium chloride, the ether layer was separated and dried over anhydrous magnesium sulfate. Evaporation of ether on a water bath gave an oil which was trituated with absolute ethanol to give 0.5 g. of a deep yellow compound melting at 183°.

*Anal.* Calcd. for C<sub>23</sub>H<sub>21</sub>NS: C, 83.37; H, 5.23. Found: C, 82.90; H, 5.31.

The infrared spectrum of this compound exhibited a band at 1610 cm.<sup>-1</sup> (>C=N in thiazolines<sup>21,22</sup>) but no absorption in the carbonyl region. The spectrum of the mother liquor showed absorption at 3570–3350 cm.<sup>-1</sup> (s): (—OH and —NH stretching); 1485 cm.<sup>-1</sup> (m) and 1450 cm.<sup>-1</sup> (s): (—NH—C=S).<sup>22</sup>

**Geometric Isomer of I. Method A.**—To 2-phenyl-4-benzylidene-5(4*H*)-oxazolone (m.p. 149°, 5 g.), 4 g. of thioacetic acid was added and the mixture heated at 100° for 18 hr. The residue was treated with absolute ethanol, filtered, and crystallized from a mixture of absolute ethanol and benzene, m.p. 139°. The melting point was depressed when mixed with I.

**Method B.**—I (1 g.) was suspended in 20 ml. of 48% hydrobromic acid and cooled in an ice bath. The suspension was saturated for 45 min. with anhydrous hydrogen bromide. The mixture was left overnight in a refrigerator, poured onto ice, filtered, and washed repeatedly until free of acid. The product was crystallized from a mixture of ethanol-benzene, m.p. 139°, mixture m.p., no depression.

*Anal.* Calcd. for C<sub>16</sub>H<sub>11</sub>NOS: C, 72.45; H, 4.15. Found: C, 72.50; H, 4.19.

**Isomerization to I.**—The isomer of I, m.p. 139° (0.5 g.) was heated with a mixture of 5 ml. of ethanol and 2 drops of pyridine for 5 min. The mixture was poured into water and filtered. The solid was crystallized from an ethanol-benzene mixture, m.p. 130°; mixture m.p. with I showed no depression.

**Spectral Measurements and Analyses.**—Infrared spectra were obtained on a Perkin-Elmer 21 spectrophotometer using chloroform as solvent. Microanalyses were conducted by Micro-Tech Laboratories, Skokie, Illinois.

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## Reductions with Quaternary Ammonium Borohydrides

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The ability of borohydrides to reduce certain organic functional groups is well documented in

TABLE I  
 REDUCTIONS WITH LONG-CHAIN QUATERNARY AMMONIUM BOROHYDRIDES

Compound reduced	Temp., °C.	Solvent								
		Benzene			Isopropyl alcohol			Water		
		BH <sub>4</sub> <sup>-a</sup>	Time, (hr.)	Yield (%)	BH <sub>4</sub> <sup>-a</sup>	Time (hr.)	Yield (%)	BH <sub>4</sub> <sup>-a</sup>	Time (hr.)	Yield (%)
Aldehydes										
<i>p</i> -Hydroxybenz-	25	...	...	...	A	2	95	A	2	100
	25	B	4	100	B	2	73	B	2	100
	65	A	3	95	...	...	...	...	...	...
2-Ethyl hex-	25	B	4	78	...	...	...	B	1	100
	65	A	4	86	...	...	...	...	...	...
Ketones										
Acetophenone	25	A	4	0	A	2	59	A	2	100
	25	B	4	21	B	2	64	B	2	100
	65	A	3	10	...	...	...	...	...	...
	65	B	2	8	...	...	...	...	...	...
Methyl nonyl	65	A	1	0	A	1.5	47	...	...	...
Methyl undecyl	65	B	3	0	...	...	...	...	...	...
Esters										
Ethyl benzoate	25	A	6.5	0	...	...	...	...	...	...
	65	A	3	0	A	3	14	...	...	...
	65	B	2	12	B	5	0	B	7	48
Ethyl <i>p</i> -nitrobenzoate	25	A	16	0	A	4.5	0	...	...	...
	25	B	2.5	0	...	...	...	...	...	...
	65	A	2.5	100	A	3	92	...	...	...
	65	B	2.5	100	B	2	77	...	...	...
Nitriles										
Benzonitrile	65	A	4.5	0	A	4.5	11	...	...	...
	65	...	...	...	B	6	0	...	...	...
Acid halides										
Benzoyl chloride	65	A	5	100	...	...	...	...	...	...
<i>p</i> -Nitrobenzoyl Cl	65	A	2	135	...	...	...	...	...	...
	65	A	2	131	...	...	...	...	...	...
Peroxides										
Benzoyl peroxide	25	A	3	65	A	6	100	...	...	...
	65	...	...	...	A	2	92	...	...	...

<sup>a</sup> A = cetyl trimethyl ammonium, B = tricapryl methyl ammonium.

the literature. Sodium borohydride reduces the carbonyl group of aldehydes and ketones in water, alcohol, or amines, and reduces acid chlorides in tetrahydrofuran or dioxane.<sup>1</sup> Aldehydes, ketones, acid chlorides, and esters are reduced by sodium borohydride in tetrahydrofuran solution by the addition of lithium,<sup>2</sup> magnesium, or calcium halides,<sup>3</sup> whereby the corresponding borohydride is formed *in situ*. In addition to the above functional groups, nitriles, disulfides, 1-olefins, oxides, acids, and acid anhydrides are reduced by sodium borohydride in diglyme or triglyme,<sup>4</sup> on the addition of aluminum halides<sup>5</sup> or lithium halides. All of the above listed reductions require a polar or an oxygenated solvent. Nonpolar hydrocarbons cannot be used because of the lack of solubility of commercially available borohydrides. Aluminum borohydride is known and is soluble in hydrocarbons,<sup>6</sup> but it is not available commercially and is also hazardous to handle, reacting violently with air or moisture.

The preparation of quaternary ammonium boro-

hydrides [RR'R''R'''N]BH<sub>4</sub>, by metathesis from commercial borohydrides, has been known since 1952.<sup>7</sup> The compounds reported in the literature, however, contained three or four short aliphatic groups (methyl or ethyl) and were only sparingly soluble in hydrocarbons. Recently, successful preparations have been made in these laboratories in which the quaternary ammonium cation contained longer chain hydrocarbon groups, thereby providing increased hydrocarbon solubility to these borohydrides. Cetyl trimethyl ammonium borohydride [C<sub>16</sub>H<sub>33</sub>(CH<sub>3</sub>)<sub>3</sub>N]BH<sub>4</sub>, mol. wt. 229.4, and tricapryl methyl ammonium borohydride [(C<sub>8</sub>H<sub>17</sub>)<sub>3</sub>-CH<sub>3</sub>N]BH<sub>4</sub>, mol. wt. 383.5, have been prepared. The former is a white granular solid and the latter, a grease. Both materials are stable with respect to storage, as indicated by identical active hydrogen analyses three months apart.

The improved hydrocarbon solubility of cetyl trimethyl ammonium borohydride and tricapryl methyl ammonium borohydride suggested tests of their reducing ability in nonpolar solvents. Accordingly, reductions of representative organic

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(3) J. Kollonitsch, O. Fuchs, and V. Gabor, *Nature*, **173**, 125 (1954); *ibid.*, **175**, 346 (1955).

(4) Diglyme is diethylene glycol dimethyl ether; triglyme, triethylene glycol dimethyl ether.

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TABLE II  
REDUCTIONS IN DIFFERENT HYDROCARBON SOLVENTS AT 65°

Compound reduced	Solvent								
	Benzene			Hexane			Mineral oil		
BH <sub>4</sub> <sup>-a</sup>	Time (hr.)	Yield (%)	BH <sub>4</sub> <sup>-a</sup>	Time (hr.)	Yield (%)	BH <sub>4</sub> <sup>-a</sup>	Time (hr.)	Yield (%)	
2-Ethylhexaldehyde	A	4	86	B	4	88	B	4	100
<i>p</i> -Nitrobenzoyl chloride	A	2	133	B	2	138	B	2	144
Benzoyl peroxide	A	3 <sup>b</sup>	65	B	3	93	B	3	88

<sup>a</sup> A = cetyl trimethyl ammonium, B = tripicryl methyl ammonium. <sup>b</sup> At 25°.

compounds, containing functional groups known to be reduced by borohydrides, were tried using one or both of the new quaternary ammonium borohydrides in hydrocarbon solvents, principally benzene. For comparison with the usual solvents for borohydride reductions, similar reductions were tried in isopropyl alcohol and water. Reductions were tested at room temperature or 65° or both. The results are summarized in Table I in terms of yield obtained in the specified time intervals.

The general utility of the long-chain quaternary ammonium borohydrides in various hydrocarbon solvents is indicated by several reductions listed in Table II, in which hexane and mineral oil were used as reaction solvents.

From Table I, it can be seen that there is no essential difference in reducing power between the two borohydrides used. A comparison of the results obtained in benzene shows that, as would be expected, aldehydes are reduced readily; ketones, only very slowly, even at elevated temperatures; and esters, not at all at room temperature and only slowly at higher temperatures. Peroxides and acid halides are readily reduced, while nitriles are not.

The exceptions to these generalizations are aromatic derivatives containing the *p*-nitro group. No reduction occurs at room temperature, regardless of solvent, and the *p*-nitro analog is also not reduced under these conditions. At 65°, however, ethyl *p*-nitrobenzoate and *p*-nitrobenzoyl chloride are reduced rapidly, regardless of solvent, while the unnitrated analog is either not reduced or only slowly. Furthermore, incomplete reduction of the nitro group itself is indicated in several of the runs in hydrocarbons, as shown by yields of 135–145%. The values are beyond experimental error, and are reproducible, as shown by the results with *p*-nitrobenzoyl chloride in benzene. Additional proof of this side reaction is provided by the fact that nitrobenzene itself consumes hydridic hydrogen when treated with the quaternary ammonium borohydrides at 65° in benzene. In six hours, reaction amounts to 31%, based on 1:1 stoichiometry. Additional work is planned to clarify the nature of this side reaction.

A comparison of solvents shows that specific reductions occur most easily in water, less so in an alcohol, and slowest in the hydrocarbons. Such a comparison must be made cautiously, however, for

variations in solubility of a particular compound among the different solvents undoubtedly also contribute to the ease of reduction observed. The results in Table II indicate no difference among the three hydrocarbon solvents tested.

### Experimental

**Materials.**—The cetyl trimethylammonium borohydride used was 93% pure, based on hydrogen evolution on acid hydrolysis; the tricapryl methyl ammonium borohydride, 90%. The principal contaminants were quaternary ammonium halide, and small amounts of free amine and amineborane.

Commercial organic reagents and solvents were used without further purification.

Reductions were carried out in conventional glass equipment on a 0.1–0.2 mole scale, using 50 to 100% excess borohydride (corrected for purity). Yields were calculated, based on the known stoichiometry of the reactions, from the volume of hydrogen evolved upon acid hydrolysis of unreacted borohydride at the end of each run. The known quantity of borohydride added permitted calculation of the amount of hydrogen consumed by the reaction after correction to STP, and thence the per cent yield.

The extent of experimental error in this rapid survey resulting from the limited quantities and techniques used, is estimated at a maximum of 15%.

## A New Constituent of *Daucus carota* L.: 2,4,5-Trimethoxybenzaldehyde

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Several attempts at the isolation of bitter principles from the roots, seeds, and leaves of carrots have been described in the literature prior to 1958<sup>1</sup> but they led to the separation of only amorphous uncharacterized products, apparently of glycosidic nature. A few years ago, a crystalline compound was isolated from bitter carrots<sup>2</sup> and it was proven to be 3-methyl-6-methoxy-8-hydroxy-3',4'-dihydroisocoumarin.<sup>3</sup> However, this sub-

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