Separation of a Phenol.—Evaporation of the ether yielded 0.2 g. of an oil with a phenolic odor suggestive of carvacrol. One drop, dissolved in 1 cc. of alcohol, gave an intense yellow color with ferric chloride solution; the color soon changed to a deep orange. Upon recrystallization from ether, the phenylurethan separated as a cluster of yellow needles, m. p. 134–137°. There was insufficient material for further purification.

The alkaline distillate was evaporated to 200 cc., acidified with sulfuric acid, and extracted with ether: 4.2 g. of an oily liquid were obtained. These free acids were distilled at atmospheric pressure: a fraction boiling at 95–110° was collected; the residue was rectified at 13 mm.

Identification of Acetic Acid.—The toluidide of the first fraction melted at 146–147°; a mixed m. p. with the toluidide of acetic acid showed no depression. The silver salt was ignited after recrystallization from boiling water. *Anal.* Calcd. for $C_2H_3O_2Ag$: Ag, 64.64. Found: Ag, 64.22.

Identification of *n*-Octylic Acid.—The toluidide of the rectified residue melted at 69–70° after repeated recrystallizations from dilute alcohol; a mixed m. p. with the toluidide of *n*-octylic acid showed no depression.

Identification of *n*-Decylic Acid.—The rectified residue deposited a solid acid upon standing at 5° for twelve hours: m. p. about 10°. A toluidide of this solid acid melted at 74–75° after repeated recrystallizations from dilute alcohol. The toluidide of *n*-decylic acid melted at 75–76°; mixed m. p. 74.5–75.5°.

Summary

An investigation of the chemical constituents of a Mexican distilled lime oil has established the presence of the following: α-pinene, β-pinene, *d*-limonene, dipentene, bisabolene, furfural, *n*-octylaldehyde, *n*-nonylaldehyde, *n*-decylaldehyde, lauric aldehyde, citral, *l*-borneol, geraniol, α-terpineol linalool, lauric alcohol, esters of acetic, *n*-octylic and *n*-decylic acids.

Borneol, geraniol and α-terpineol occur as free alcohols, and possibly also as esters; lauric alcohol probably occurs as an ester.

A high boiling oil of an intense blue-green color, probably an azulenic compound, was separated.

An unidentified aldehyde with an odor suggestive of cuminic aldehyde was not obtained in a state of sufficient purity for identification.

The presence of a trace of a phenol or phenolic ester was also established, although it was not identified.

The presence of phellandrene, *p*-cymene, terpinene, cadinene, or high boiling paraffinic hydrocarbons could not be established.

NEW YORK, N. Y. RECEIVED FEBRUARY 25, 1943

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, THE UNIVERSITY OF TEXAS]

Conversion of Δ^2-Cyclohexenones and Cyclohexanones into Spirohydantoins[1]

BY HENRY R. HENZE, ROBERT CURTIS WILSON[2] AND ROBERT W. TOWNLEY[3]

During the past few years a considerable number of derivatives of hydantoin have been prepared in this Laboratory. These compounds have been tested elsewhere[4] and many have been shown to possess mild pharmacological activity, some as anticonvulsants and others as soporifics. As in the case of the barbiturates, some correlation may be noted between the type of activity and the structure of the substituents attached at the 5-position of the hydantoin nucleus. To date very few spirohydantoins[5] had been prepared for the purpose of being tested; this study supplied some examples of the desired type.

Substituted cyclohexanones react readily with aqueous–alcoholic solutions of potassium cyanide and ammonium carbonate to yield the anticipated substituted spirohydantoins. However, when Δ^2-cyclohexenones are condensed, addition of two equivalents of hydrogen cyanide leads to the formation of cyanospirohydantoins. When certain Δ^2-cyclohexenones are treated with alkali bisulfite and the products exposed to the action of potassium cyanide and ammonium carbonate solution, spirohydantoins containing a sulfonic acid substituent are obtained.

Five of these spirohydantoins have received preliminary pharmacological testing through the courtesy of Parke, Davis and Company. The spirohydantoin derived from 3-ethyl-5-methylcyclohexanone exhibited neither hypnotic nor anticonvulsant activity. However, the phenyl analog, namely, 2,4-dioxo-7-methyl-9-phenyl-1,3-diazaspiro(4,5)decane, did evidence a mild degree

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(1) From the Ph.D dissertation of R. C. Wilson, June, 1941.

(2) Present address: General Aniline and Film Corporation, Grasselli New Jersey.

(3) Present status: Past Assistant Public Hygiene Engineer U. S. Public Health Service.

(4) Our indebtedness to Parke, Davis and Company for this service is gratefully acknowledged.

(5) Henze and Speer [THIS JOURNAL, **64**, 522 (1942)] recorded the melting points of a few examples, but omit details of preparation and pharmacological activity.

TABLE I

3-METHYL-5-R-CYCLOHEXANONES

R	B. p., °C.	B. p., mm.	Yield, %	$n^{20}D$	d^{20}_4	Mol. refract. Calcd.	Mol. refract. Found	Semicarbazone m. p., °C. (cor.)
Methyl[a]	181–182	750	78	1.4427	0.8950	36.96	37.35	200.0–200.5
Ethyl[b]	204–205	747	94	1.4452	0.8987	41.57	41.54	189.0–190.0[c]
Phenyl[d]	180–181	26	69	1.5431	1.0238	56.44	57.17	111.5–112.0[e]
α-Furyl[f]	147–148	22	79	1.4998	1.0619	49.32	49.32	172.0–173.0[g]

[a] Wallach [*Ann.*, **397**, 199 (1913)] reported b. p. 182°; $n^{19}D$ 1.4425; d^{19}_4 0.895; *M*R calcd. 37.00; *M*R found 37.29; semicarbazone m. p. 201°.

[b] *Anal.* Calcd. for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 76.91; H, 11.57.

[c] *Anal.* Calcd. for $C_{10}H_{19}N_3O$: N, 21.30. Found: N, 21.42.

[d] Knoevenagel [*Ann.*, **303**, 265 (1898)] reported b. p. 168–170° (16 mm.) and m. p. of oxime 105°.

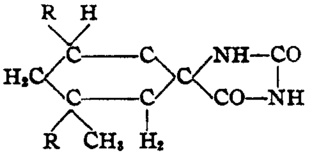
[e] *Anal.* Calcd. for $C_{13}H_{17}NO$: N, 6.89. Found: N, 6.87.

[f] *Anal.* Calcd. for $C_{11}H_{14}O_2$: C, 74.13; H, 7.92. Found: C, 73.97; H, 8.00.

[g] *Anal.* Calcd. for $C_{12}H_{17}N_3O_2$: N, 17.86. Found: N, 17.96.

TABLE II

SPIROHYDANTOINS: 2,4-DIOXO-7-METHYL-7-R-9-R′-1,3-DIAZASPIRO(4,5)DECANES



R	R′	M. p., °C. (cor.)	Yield, %	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found	Sulfur, % Calcd.	Sulfur, % Found
H	CH_3	335–336	76	61.20	61.11	8.22	8.18	14.28	14.23		
H	C_2H_5	282(dec.)	75	62.83	62.78	8.63	8.56	13.32	13.22		
H	C_6H_5	223–224	46	69.74	69.77	7.02	7.05	10.85	11.18		
H	C_4H_3O[a]	223–224(dec.)	78	62.89	63.11	6.50	6.72	11.28	11.37		
CN	CH_3	196–197	55	59.66	59.63	6.83	6.85	18.99	18.92		
CN	C_2H_5	173–174	54	61.21	61.14	7.28	7.33	17.85	17.87		
CN	C_6H_5	221	50	67.82	67.52	6.05	6.09	14.84	14.62		
CN	C_4H_3O[a]	210–211[b]	86	61.53	61.44	5.53	5.61	15.45	15.28		
CH_2NH_2	C_2H_5	223	33	60.22	60.04	8.85	8.79	17.56	17.52		
SO_3K	CH_3		73					8.91	8.73	10.20	10.06
SO_3K	C_2H_5		54					8.53	8.45	9.76	9.62
SO_3H	C_2H_5	175(dec.)						9.65	9.77	11.04	10.95
SO_3H	C_6H_5	273–275 (dec.)	20					8.28	8.28	9.50	9.39
SO_3K	C_4H_3O[a]		80					7.65	7.55	8.75	8.79

[a] α-Furyl. [b] After fusion and resolidification, remelts at 215°.

of anticonvulsant activity. Introduction of a sulfonic acid grouping at the 7-position of these two spirohydantoins, as well as in the 7-methyl-9-α-furyl analog, caused considerable reduction in the toxicity but did not enhance the activity of these compounds.

Experimental

The unsaturated cyclic ketones used were 3,5-dimethyl-Δ²-cyclohexenone,[6] 3-methyl-5-ethyl-Δ²-cyclohexenone,[7] 3-methyl-5-phenyl-Δ²-cyclohexenone[6] and 3-methyl-5-α-furyl-Δ²-cyclohexenone. These ketones were prepared[6] by mixing two equivalents of ethyl acetoacetate with one of the appropriate aldehyde; the addition of 1–5 cc. of diethylamine sufficed to start the reaction which was evidenced by the evolution of considerable heat. The reaction mixture was allowed to stand at room temperature for about forty-eight hours, and then was heated to boiling under reflux condenser with either 20% sulfuric acid or 10% potassium hydroxide solution. The cyclohexenones were obtained by steam distillation, dried and fractionated.

The following data were noted for 3-methyl-5-ethyl-Δ²-cyclohexenone[8]: b. p. 106° (18 mm.); $n^{20}D$ 1.4880; d^{20}_4 0.9607; *M*R calcd. 41.11; *M*R found 41.32. For 3-methyl-5-phenyl-Δ²-cyclohexenone, b. p. 210° (26 mm.)[9]; $n^{20}D$ 1.5580; d^{20}_4 1.0712; *M*R calcd. 55.98; *M*R found 56.05. The data observed for physical properties of 3,5-dimethyl-Δ²-cyclohexenone and for 3-methyl-5-α-furyl-Δ²-hexenone agree closely with those recorded by Knoevenagel.

The (saturated) cyclohexanones were prepared by dissolving 0.1 mole of a substituted Δ²-cyclohexenone in 50 cc. of ethyl alcohol, adding 0.1 g. of the Adams catalyst and shaking with hydrogen under about two atmospheres pressure. The dimethyl derivative was reduced in about

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(6) Knoevenagel, *Ann.*, **281**, 94 (1894).

(7) Wallach, *ibid.*, **323**, 145 (1902).

(8) Wallach, ref. 7, reported only b. p. 102° (14 mm.) and 232° (atm. press.).

(9) Knoevenagel, ref. 6, reported only b. p. 202.0–202.5° (30 mm.).

one hour, while the α-furyl ketone required twelve hours. Data for certain physical properties of the cyclohexanones are listed in Table I

Preparation of Spirohydantoins.—These compounds were synthesized by the method of Bucherer[10] except that the amount of cyanide was doubled when the substituted Δ^2-cyclohexenones were used. This increase is required since it has been shown[11] that hydrogen cyanide adds to an ethylenic linkage when the latter is conjugated with a carbonyl group, as in these Δ^2-cyclohexenones. Likewise, it has been demonstrated[12] that sulfurous acid and alkali bisulfites add to the ethylenic linkage of Δ^2-cyclohexenones just as hydrogen cyanide does. Hence, by preliminary treatment of these ketones with alkali bisulfite solution, sulfonic acids of the spirohydantoins were produced.

Preparation of 2,4-Dioxo-7-aminomethyl-9-ethyl-7-methyl-1,3-diazaspiro(4,5)decane.—This compound was prepared by the reduction of 6 g. of the corresponding cyano compound (2,4-dioxo-7-cyano-9-ethyl-7-methyl-1,3-diazaspiro(4,5)decane), which was dissolved in 100 cc. of anhydrous amyl alcohol and treated with 4.5 g. of metallic sodium according to the method of Suter and Moffett[13] for the reduction of cyano compounds to the corresponding primary amines. After reduction was complete, careful neutralization caused separation of 2 g. (33% yield) of crystalline material melting at 223°. Although a carbylamine test failed and a picrate could not be formed, the compound reacted readily with nitrous acid to form nitrogen. Hence, the compound was analyzed for primary amino nitrogen by the micro method of Van Slyke.[14]

Anal. Calcd. for $C_{12}H_{21}N_3O_2$: C, 60.22; H, 8.85; total N, 17.56; primary amino N, 5.85. Found: C, 60.04; H, 8.79; total N, 17.52; primary amino N, 5.76.

The spirohydantoins were found to be markedly more soluble in water and in alcohol than the cyano-spirohydantoins; both types are readily soluble in alkaline solution and are reprecipitated unchanged upon acidification. The spirohydantoin-sulfonic acids are very soluble in water and in alcohol, while their potassium salts are less soluble than the acids. However, treatment of the potassium sulfonate derivative of the α-furyl-spirohydantoin with strong acids resulted in decomposition.

Summary

1. Four substituted Δ^2-cyclohexenones were converted by means of interaction with potassium cyanide and ammonium carbonate, into spirohydantoins containing a cyano substituent.

2. From four substituted cyclohexanones were obtained the anticipated spirohydantoin derivatives.

3. A third type of spirohydantoin, containing a sulfonic acid grouping, was obtained by initial treatment of the Δ^2-cyclohexenones with alkali bisulfite solution followed by reaction with alkali cyanide and ammonium carbonate.

AUSTIN, TEXAS RECEIVED FEBRUARY 27, 1943

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[10] Bucherer and Lieb, *J. prakt. Chem.*, [2] **141**, 5 (1934).

[11] Knoevenagel, *Ber.*, **37**, 4065 (1904).

[12] Knoevenagel, *ibid.*, **37**, 4038 (1904).

[13] Suter and Moffett, THIS JOURNAL, **56**, 487 (1934).

[14] Van Slyke, *J. Biol. Chem.*, **16**, 121 (1913).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF NOTRE DAME]

The Addition of Hydrogen to Multiple Carbon–Carbon Bonds. IV. The Electrolytic Reduction of Alkyl and Aryl Acetylenes[1]

BY KENNETH N. CAMPBELL AND ELDRED E. YOUNG

Practically no work has been reported in the literature on the electrolytic reduction of compounds containing carbon–carbon unsaturation unactivated by an adjacent carbonyl group. A few unsaturated acids such as oleic acid have been reduced electrolytically at nickel and copper cathodes, and the electrolytic reduction at a copper cathode of some acetylenic carbinols has been reported.[2] We have found no mention of attempts to reduce acetylenic or ethylenic hydrocarbons electrolytically except for the work of Billitzer,[3] who reduced acetylene gas at a platinized platinum cathode to ethylene, and of Laitinen and Wawzonek,[4] who reduced aryl substituted olefins and acetylenes at a dropping mercury electrode.

Wilson[5] has pointed out that electrolytic reduction of conjugated compounds such as sorbic acid at high over-voltage cathodes resembles reduction by dissolving metals, and presumably occurs by a similar mechanism, while electrolytic reduction at low over-voltage cathodes, such as nickel and platinum, resembles catalytic hydrogenation. In earlier papers from this Laboratory[6,7] we have shown that dialkylacetylenes can be reduced by sodium in liquid ammonia to the *trans*-olefins, while catalytic hydrogenation of the

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[1] Paper III, THIS JOURNAL, **63**, 2683 (1941). Paper XLV on substituted acetylenes and their derivatives; previous paper, *ibid.*, **64**, 1220 (1942).

[2] Campbell and Campbell, *Chem. Rev.*, **31**, 129 (1942).

[3] Billitzer, *Monatsh.*, **23**, 199 (1902).

[4] Laitinen and Wawzonek, THIS JOURNAL, **64**, 1765 (1942).

[5] Wilson, *Trans. Electrochem. Soc.*, **75**, 353 (1931).

[6] Campbell and Eby, THIS JOURNAL, **63**, 216 (1941).

[7] Campbell and Eby, *ibid.*, **63**, 2683 (1941).