acetylene gas was passed into the solution until the blue color of the solution was discharged, after which 21.3 g. of 3-methyl-3-hydroxy-2-butanone was added dropwise with stirring. After a reaction period of four hours, the processing steps included distilling off the ammonia, dissolving the residue in water, extracting the solution with ether, drying over potassium carbonate and distilling. The yield of product collected at 75-77° (6 mm.) was 22.9-24.3 g. (86-91%); n^{25}_{D} 1.4600; d^{25}_{4} 1.001.

Anal. Calcd. for $C_7H_{12}O_2$: C, 65.59; H, 9.43. Found: C, 65.42; H, 9.11.

Diacetate.—A solution was prepared containing 5.5 g. of III, 20-25 g. of benzene, and two drops of sulfuric acid previously dissolved in ether. Ketene was passed into this solution for an hour at room temperature then for thirty minutes at 70-75°. Acidic impurities were removed by rinsing with sodium bicarbonate solution and with water. Then, after drying, the solvent was removed. Most of the product distilled at 120° (15 mm.); yield, 4.2 g. The thick, colorless distillate set to a crystalline mass within a few minutes; m. p. 54-56°. The crystals were very soluble in most organic solvents, including ligroin. The product is very volatile in steam.

Crystallization from solvents was not an easy matter. A 9:1 water-alcohol mixture maintained below 45° (to avoid liquefying the crystals) was the best solvent found. Purification is more readily achieved by sublimation. With conditions chosen at 130° and 40 mm. pure crystals were obtained melting at 55.0-55.5° (uncor.).

Anal. Calcd. for $C_{11}H_{16}O_4$: C, 62.25; H, 7.60. Found: C, 62.62; H, 7.60.

Acknowledgments.—This investigation was supported by a grant during 1942 from the Graduate School of Northwestern University. Micro combustion analyses were performed by Dr. T. S. Ma. Assistance in the purification of the diacetate was given by Dr. Arthur Berger.

Summary

3,4-Dimethyl-4-pentyne-2,3-diol and its diacetate are described. Attention is called to the fact that the hydration product of the former, namely, 3,4-dimethyl-3,4-dihydroxy-2-pentanone may be regarded as a monosaccharide composed of tertiary alcohol groups.

EVANSTON, ILLINOIS RECEIVED AUGUST 23, 1948

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY AND CHEMICAL ENGINEERING OF THE UNIVERSITY OF WASHINGTON]

Studies of Hemiacetal Formation in Alcohol–Aldehyde Systems. I. Cryoscopic Studies

BY F. E. MCKENNA,[1] H. V. TARTAR AND E. C. LINGAFELTER

The existence of an equimolar addition compound between an alcohol and an aldehyde was probably first mentioned by Jacobson.[1a] He considered the structure to be $CH_3CHOHOC_2H_5$ and called it an aldehyde alcoholate. Perkin[2] noted an initial decrease followed by a rapid increase in temperature when an aldehyde is mixed with an alcohol or water; this change was ascribed to a depolymerization of the alcohol or water followed by compound formation. The term hemiacetal came to be used for this type of supposed addition compound because of the purported relationship to the well-known acetal molecule.

Several more recent workers have investigated binary mixtures of aldehydes and alcohols for evidence on the existence of the hemiacetal. Wolf and Merkel[3] have confirmed Perkin's finding on the temperature changes when aldehydes and alcohols are mixed together. Curves representing density or index of refraction as a function of the composition presented by Adkins and Broderick[4] showed maxima at 50 mole per cent. Herold and Wolf[5] using absorption spectra measurements found maximum absorption with equimolar proportions, the band due to the carbonyl group being replaced by one characteristic of the ether-like linkage ascribed to the hemiacetal. They observed a time lag for this change of absorption which was attributed to the gradual establishment of a hemiacetal–alcohol–aldehyde equilibrium.

De Leeuw[6] determined the freezing point curve for the system acetaldehyde–ethanol. He found two maxima with aldehyde to alcohol ratios of 1:1 and 1:2. He also postulated that the latter compound in the presence of a dehydrating agent or of a catalyst could lose water to form the acetal.

Schimmel and Company[7] reported that mixtures of aliphatic alcohols and aldehydes (*n*-heptyl to *n*-undecyl) gave crystalline compounds of constant composition, 1:1. They were unable to prepare any derivatives of these substances because the reagents caused dissociation to aldehyde and alcohol.

The present results reported herein are from a cryoscopic investigation of the systems: *n*-heptanol–*n*-heptaldehyde, and methanol–propionaldehyde. Previously Schimmel and Company[7] had reported a melting point of 2° for the product obtained from an equimolar mixture of *n*-heptanol and *n*-heptaldehyde. The system methanol–propionaldehyde affords compounds with the smallest alkyl groups adapted to convenient investigation.

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[1] Present address: Air Reduction Sales Co., Research Laboratories, Murray Hill, New Jersey.

[1a] Jacobson, *Ber.*, **4**, 215 (1871).

[2] Perkin, *J. Chem. Soc.*, **45**, 477 (1881); **51**, 826 (1887).

[3] Wolf and Merkel, *Z. physik. Chem.*, **187**, 61 (1940).

[4] Adkins and Broderick, THIS JOURNAL, **50**, 499 (1928).

[5] Herold and Wolf, *Z. physik. Chem.*, **2B**, 39 (1928); **12B**, 194 (1931); **16B**, 213 (1932); **18B**, 265 (1932); *Z. Elektrochem.*, **38**, 633 (1932); **39**, 566 (1933).

[6] De Leeuw, *Z. physik. Chem.*, **77**, 284 (1911).

[7] Schimmel and Co., *Ann. Reports*, p. 71 (1933).

Experimental

Purification of Materials.—(a) **Propionaldehyde** was furnished by the Eastman Kodak Co. (White Label); boiling point range 47.8 to 50.5°. It was found that propionaldehyde cannot be kept pure in the presence of air. When distillation was attempted in air a yellow oily substance was produced. Qualitative tests with ammonium thiocyanate to which a crystal of ferrous (free of ferric) ammonium sulfate had been added showed that peroxides were formed and that this was accompanied by an increase in the refractive index from n^{25}_{D} 1.3601 to 1.3630 at room temperature. The rate of change was dependent upon the previous treatment (acidic or alkaline) of the Pyrex flasks even though followed by quite thorough rinsing with distilled water. Brühl[8] has reported the refractive index, n^{20}_{D} 1.3636.

Consequently all samples of propionaldehyde were purified by distillation under nitrogen and collected in glass containers which had been previously boiled out with water for twenty to thirty minutes and dried. The fraction boiling at 48.0 ± 0.05° (760 mm.) was used for all measurements. The refractive index was n^{25}_{D} 1.3601 and the freezing point −80.05°. Walden[9] has reported the freezing point to be −81°.

Buckler[10] has stated that his samples of propionaldehyde polymerized spontaneously, even at low temperatures. Such behavior was not observed in this investigation.

(b) **Methanol.**—The material used was the fraction which distilled at 64.6 ± 0.05° (760 mm.). The fractionation was effected under nitrogen to prevent the formation of peroxides. The freezing point was found to be −98.02°. Previous investigators[11] have reported freezing points ranging from −97.0° to −98.54°, the average being −97.6°.

A transition temperature was found by Parks[12] to be −112° and by Kelley[13] −115.7° with supercooling as much as 25° obtainable. A transition temperature of −113.5° was observed with the methanol used in this investigation.

(c) **n-Heptanol.**—The n-heptanol distilled at 175.4 ± 0.05° (760 mm.) from the Eastman Kodak Co. product (White Label). This was further purified by fractionation under nitrogen; freezing point −34.03°. Deffet[14] reports: f. p., −34.1°; b. p. 176.35°.

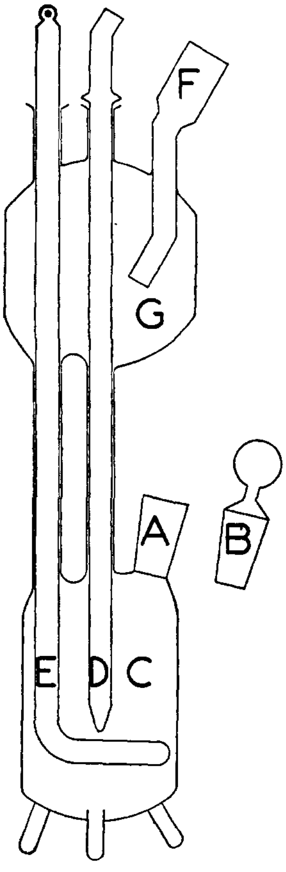

Fig. 1.—Cryostat.

(d) **n-Heptaldehyde.**—The n-heptaldehyde (Eastman White Label) distilled at 152.6 ± 0.05° (760 mm.). To prevent peroxide formation it was fractionated under nitrogen into previously boiled-out flasks. The freezing point was −43.71°. Deffet[14] reported f. p., −43.3°; b. p., 152.8°.

A slight charring of the residual liquid was observed during the fractionation (760 mm.) of both n-heptanol and n-heptaldehyde.

Apparatus.—The original plan was to construct the cryostat of a metal of high thermal conductivity. It was found that solutions of aldehydes and alcohols react with metals, in some cases forming crystalline compounds. Consequently the compounds were distilled in a nitrogen atmosphere directly into the glass cryostat. This apparatus is a modification of that described by Kanolt[15] and is shown in Fig. 1. The ground-glass joint A fits the adapter at the condenser. At other times this opening can be closed with the ground-glass stopper B. The liquids under investigation are contained in bulb C. The thermo-element tube D is removable. E is the stirrer. F is a small funnel for the addition of a small drop of liquid air to induce crystallization in case a solution should supercool. The bulb G permits the circulation of dry nitrogen around the stirrer and the thermo-element tubes to prevent the entry of moist air.

The distillation apparatus consisted of a 500-ml. distilling flask to the neck of which was attached a glass column, 25 cm. long, 1.3 cm. diam., packed with small glass helices. The outlet of the condenser was provided with a ground-glass joint to fit the inlet of the cryostat. A ground-glass cap with a sealed-in tube admitted a slow stream of purified nitrogen into the distilling flask.

The cryostat was placed in an unsilvered, one-liter Dewar flask. The gas pressure between the walls could be varied by means of a vacuum pump, thus allowing control of the rate of cooling or warming of the material in the cryostat. This Dewar, in turn, was contained in a five-liter, silvered, Dewar flask.

The refrigerant in the outer Dewar was liquid air, for the methanol-propionaldehyde system, and solid carbon dioxide in acetone, for the n-heptanol-n-heptaldehyde system. The cryostat was surrounded by a bath liquid (contained in the unsilvered Dewar) having the following composition by weight: 16.2% chloroform, 28.2% methylene chloride, 37.3% ethyl bromide and 18.3% trichloroethylene. This is similar to the bath liquid suggested by Kanolt[15] as not flammable and freezing around −150°.

Temperature Measurements.—The temperatures in the cryostat were measured with a two-junction copper-constantan thermo-element. This was constructed of Leeds and Northrup no. 38 copper and no. 30 constantan wire, which was free of inhomogeneities. The junctions were spot-welded. The thermo-element was given two coats of Bakelite varnish, then wrapped with silk binding tape and given an outer coat of Bakelite varnish. The element was placed in tube D of the cryostat and molten naphthalene poured around it to afford good heat transmission. The e. m. f. was measured with a Leeds and Northrup White Single Potentiometer of 10,000 microvolt range, and a Leeds and Northrup HS galvanometer. The thermo-element was calibrated at the temperatures of melting ice, melting mercury, subliming carbon dioxide and boiling oxygen.

Procedure.—The cryostat was steamed out for thirty minutes and dried. The weighed cryostat was attached to the distilling apparatus and a slow stream of nitrogen passed in to flush out the air. Then the components of the solution were distilled into the cryostat.

The unsilvered Dewar flask was evacuated to reduce heat transfer. The cryostat was immersed in the bath liquid and the cooling begun by admitting some gas to the space between the walls.

In determining melting points, a very small amount of refrigerant was kept in the outer Dewar to ensure slow heating not too far removed from equilibrium conditions.

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(8) Brühl, *Ann.*, **200**, 139 (1880).

(9) Walden, *Z. physik. Chem.*, **55**, 220 (1899).

(10) Buckler, *J. Chem. Soc.*, 1036 (1937).

(11) Kelley, This Journal, **51**, 180, 779, 1145 (1929); Keyes, *J. Math. Physics* (*MIT*), **1**, 243 (1922); Joukovsky, *Bull. soc. chim. Belg.*, **43**, 397 (1934); Roper, This Journal, **60**, 1693 (1938); Ross and Summerville, *J. Chem. Soc.*, 2770 (1926); Stull, This Journal, **59**, 2726 (1937); Timmermans, *J. chim. phys.*, **27**, 401 (1930).

(12) Parks, This Journal, **47**, 338 (1925).

(13) Kelley, *ibid.*, **51**, 180 (1929).

(14) Deffet, *Bull. soc. chim. Belg.*, **40**, 385 (1931).

(15) Kanolt, *U. S. Bur. Standards, Sci. Paper* No. 520.

Upon completion of the measurements on a given solution, the cryostat was removed from the bath, brought to room temperature and reweighed. In no case was any loss observed.

Results

The freezing-point composition data for *n*-heptanol–*n*-heptaldehyde are presented in Table I and Fig. 2. The maximum at 2.25° for the solution with equimolar concentrations shows compound formation (hemiacetal) between one molecule of *n*-heptaldehyde and one molecule of *n*-heptanol.

TABLE I

FREEZING POINT–COMPOSITION DATA FOR THE SYSTEM: *n*-HEPTANOL–*n*-HEPTALDEHYDE

Alcohol, mole fraction	Freezing point, °C. Primary	Eutectic	Alcohol, mole fraction	Freezing point, °C. Primary	Eutectic
0.000	−43.71	.....	0.456	+ 1.57	−58.44
.037	−46.11	−58.92	.489	+ 2.25	.....
.074	−50.44	−58.92	.594	+ 0.47	−50.02
.108	.....	−58.92	.662	− 4.16	.....
.143	−48.15	−58.92	.715	−10.31	.....
.187	−34.52	−58.87	.777	−26.04	.....
.238	−19.69	−58.92	.794	−32.97	−50.07
.296	− 7.85	.....	.829	−44.92	−50.13
.353	− 1.98	.....	.849	−49.06	−50.13
.401	+ 0.33	.....	.877	−45.27	−50.13
			1.000	−34.03	.....

It was observed that a solid having a composition between that of A and of B could be superheated, the amount depending on the rate of warming. In some cases it was possible to superheat the solid to the melting temperature of the compound C.

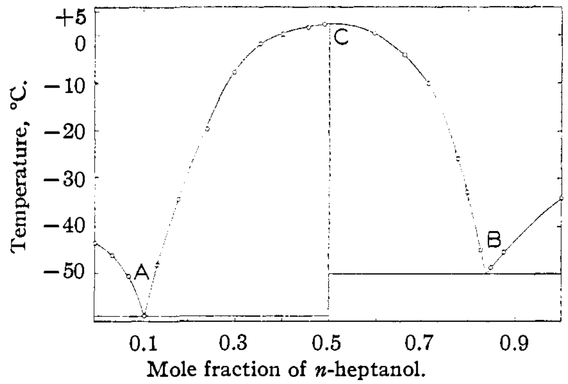


Fig. 2.—Freezing points for the *n*-heptanol–*n*-heptaldehyde system.

Also it was possible to produce a rather high degree of supercooling of some solutions with compositions intermediate between A and B. This was prevented by slow cooling, by seeding the solution with some of the solid or by dropping a small amount of liquid air onto the surface of the solution.

The freezing point–composition data for the methanol–propionaldehyde system are presented in Table II and Fig. 3. Here also a maximum, higher than the melting point of either component of the system, was found at −66.75° for equimolar concentrations of aldehyde and alcohol.

TABLE II

FREEZING POINT–COMPOSITION DATA FOR THE SYSTEM: METHANOL–PROPIONALDEHYDE

Alcohol, mole fraction	Freezing point, °C. Primary	Eutectic	Transition, °C.
0.000	− 80.05	.....	
.094	− 96.15	−114.9	
.151	−112.2	−114.9	
.249	− 91.17	−114.9	
.353	− 74.84	−114.9	
.502	− 66.75	.....	−117.3
.606	− 75.49	−134.0	−118.5
.706	−101.1	−134.0	−120.5
.793	−132.9	−134.0	.....
.859	−114.0	−134.0	−118.4
.982	− 99.53	−134.0	−114.3
1.000	− 98.02	.....	−113.5

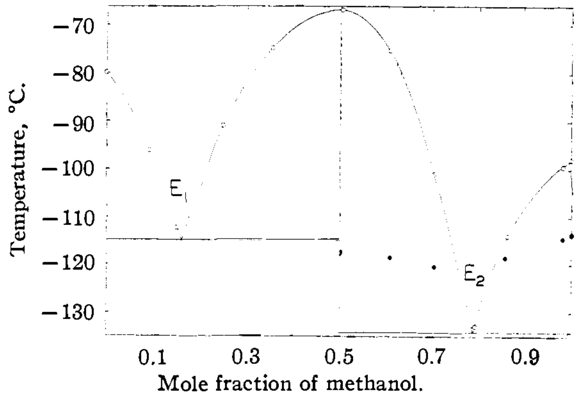


Fig. 3.—Freezing points and transition temperatures for the methanol–propionaldehyde system: ○, freezing points; ●, transition temperature.

No superheating was observed in this system; the supercooling was also negligible. In a few instances the solution set to a jelly-like transparent solid but a slight movement of the stirrer caused the jelly-like material to become a crystalline solid.

The transition temperature of methanol was observed in all cases where the solid phase was the alcohol. A transition was also observed in compositions varying from eutectic E_2 and 50 mole per cent. methanol; the temperature varied from −113.5 to −120.5°.

The maximum in the curve for the *n*-heptanol–*n*-heptaldehyde system is broader and flatter than that for the methanol–propionaldehyde system. This indicates that the larger hemiacetal molecule is more dissociated than the smaller one. The fact that the system involving the smaller hemiacetal did not supercool or superheat to the extent of that with the larger hemiacetal, may indicate that equilibrium is reached more rapidly between the smaller alcohol and aldehyde molecules.

The solid which separated from a solution which was relatively rich in one of the components was finely divided; the solid formed from a solution of approximately equimolar proportions was in larger crystals.

Summary

1. The effect of previous treatment of glass surfaces on the properties of propionaldehyde stored in glass vessels has been pointed out.

2. A cryostat has been constructed for use in cryoscopic investigations in solutions of alcohols and aldehydes.

3. The freezing point–composition relationships have been investigated for the systems: (a) *n*-heptanol–*n*-heptaldehyde and (b) methanol–propionaldehyde.

4. The results prove the formation of a compound (hemiacetal) between one molecule of an alcohol and one molecule of an aldehyde.

SEATTLE, WASHINGTON RECEIVED SEPTEMBER 30, 1948

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

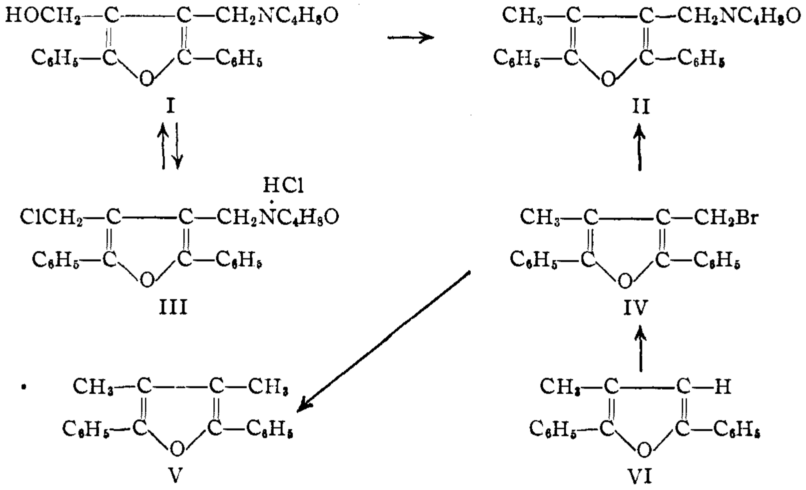
3-(Hydroxymethyl)-4-(morpholinylmethyl)-2,5-diphenylfuran and Some Derivatives[1,2]

BY PHILIP S. BAILEY AND GENE NOWLIN

In an earlier paper[3] was described the isolation of 3-(hydroxymethyl)-4-(morpholinylmethyl)-2,5-diphenylfuran (I) from a Mannich reaction employing 1,2-dibenzoylethane, paraformaldehyde and morpholine hydrochloride in benzene solution. As stated there, the identity of I was not at first apparent. The present paper deals principally with reactions which led to its identification and some interesting reactions of its derivatives. Improvement in the yield of I is reported. The generality of the reaction leading to I has also been demonstrated by the fact that piperidine hydrochloride gives similar results.

Reduction of I by means of hydriodic acid or by stannous chloride gave II, the structure of which was established by synthesis from 3-methyl-2,5-diphenylfuran (VI). This consisted of the bromomethylation of VI to give IV, followed by treatment of IV with morpholine. Any possible doubt as to the course of the bromomethylation reaction was removed by the catalytic hydrogenolysis of IV to give known 3,4-dimethyl-2,5-diphenylfuran (V). Treatment of I with a chloroform solution of hydrogen chloride gave 3-(chloromethyl)-4-(morpholinylmethyl)-2,5-diphenylfuran hydrochloride (III) which in turn was easily converted back to I. The chloromethyl compound (III) also was made by the chloromethylation of 3-(morpholinylmethyl)-2,5-diphenylfuran. These reactions confirm the structure assigned to I because of reactions reported earlier.[3,4]

The structures of the two products of the Mannich reaction using piperidine hydrochloride (2,5-diphenyl-3-[piperidylmethyl]-furan and 3-[hydroxymethyl]-2,5-diphenyl-4-[piperidylmethyl]-furan) were proven by characteristic syntheses starting from 3-(bromomethyl)-4-chloro-2,5-diphenylfuran, syntheses earlier carried out for the corresponding morpholine compounds.[4]



1,2-Dibenzoyl-1-methyl-2-(morpholinylmethyl)-ethylene (VII) was prepared by the characteristic nitric acid oxidation[5] of II and was found to give some interesting reactions. Reductive furanization of VII back to II, either directly or stepwise through VIII, establishes the structure of VII. When VII is treated with 6 N hydrochloric acid it dissolves, and when the resulting solution is neutralized with sodium carbonate, a product shown to be I crystallizes.

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[1] Presented before the Southwest Regional Meeting of the American Chemical Society, Shreveport, Louisiana, December 10, 1948. A small portion was included in a paper presented at the Chicago meeting of the American Chemical Society, April, 1948.

[2] This work was partially supported by a University of Texas Research Institute grant, Project 70, and by a Frederick Gardner Cottrell grant from the Research Corporation, New York, N. Y.

[3] Bailey and Lutz, THIS JOURNAL, **70**, 2412 (1948).

[4] Lutz and Bailey, *ibid.*, **68**, 2002 (1946).

[5] Lutz and Wilder, *ibid.*, **56**, 978 (1934).