couple. The apparatus was calibrated at the freezing points of water, carbon tetrachloride and chloroform.

The freezing point cell contained a glass spiral with an enclosed iron slug at the upper end.[4] Stirring was effected by applying an intermittent current to an air-cooled solenoid placed around the neck of the cell. A thermocouple well was built into the cell. Petroleum ether (30–60° fraction) was used as a heat transfer medium in the thermocouple well to minimize convection effects within this well.

The system $Al(C_2H_5)_3$–$(C_2H_5)_2O$.—The aluminum triethyl was vacuum-distilled into the cell and then nitrogen was admitted. The cell was weighed to determine the amount of aluminum triethyl. Additions of ether were made by a hypodermic syringe through a serum bottle stopper, the amounts being determined by weighing the cell.

Cooling was effected by either a Dry Ice–acetone slurry or liquid nitrogen. Single, double or evacuated jackets were used to control the rate of cooling to around 0.5 to 2° per minute.

While the method is capable of accuracy within ±1.5°, the extreme reactivity of aluminum triethyl and consequent difficulty in obtaining and keeping it pure, the apparent low heats of fusion which make it difficult to obtain sharp changes of slope in the cooling curve, and the tendency of the mixtures to supercool make the freezing points obtained from 0 to 80 mole % ether probably accurate to within ±2°. From 80 mole % to 100 mole % it was necessary to determine most of the freezing points visually, as the formation of solid did not affect the slope of the time–temperature curve enough to be detected.

The freezing point–composition curve for the system is shown in Fig. 1. The values obtained for the freezing point of aluminum triethyl were −50.3 and −50.7°, as compared with a melting point of −52.5° reported by Pitzer and Gutowsky[5] using a pentane thermometer. The formation of a compound between aluminum triethyl and diethyl ether is indicated by the maximum in the curve at about −65° and 50 mole %. There are eutectics at 34 mole % ether, −71°, and at 96 mole % ether, −119°.

The results of the cryoscopic studies indicate that the addition compound has the formula $Al(C_2H_5)_3 \cdot (C_2H_5)_2O$. However, the maximum in the freezing point curve is rather flat, and, in view of the experimental difficulty encountered in determining portions of the curve, the results though reasonably convincing cannot be considered to be completely conclusive. To remove any remaining doubt the following additional evidence was obtained: 1. Samples of the etherate of aluminum triethyl prepared by the method of Krause and Wendt[2] and purified as carefully as possible gave freezing points (−64°, −64.5°) agreeing well with the maximum in the freezing point curve (−65°). 2. Changes in the freezing points of these prepared samples produced by the addition of known quantities of ethyl ether fit the freezing point curve closely if it is assumed that the prepared samples contain the metal alkyl and ether in a 1:1 mole ratio. The freezing points do not lie upon the curve if it is assumed that the prepared samples contain metal alkyl and ether in a 4:3 ratio. 3. Carefully purified samples of the etherate of aluminum triethyl were analyzed for aluminum by hydrolysis and precipitation of the aluminum as the 8-hydroxyquinolate. Found: Al, 14.31, 14.46 (two different preparations). Calcd. for $4Al(C_2H_5)_3 \cdot 3(C_2H_5)_2O$: Al, 15.89. Calcd. for $Al(C_2H_5)_3 \cdot (C_2H_5)_2O$: Al, 14.33.

Conclusion.—In consideration of the evidence presented it must be concluded that the composition of the etherate of aluminum triethyl is correctly represented by the formula $Al(C_2H_5)_3 \cdot (C_2H_5)_2O$ and that the earlier report of Krause and Wendt[2] is in error.

(4) B. Rubin, H. Sisler and H. Shechter, THIS JOURNAL, **74**, 877 (1952).

(5) K. S. Pitzer and H. S. Gutowsky, *ibid.*, **68**, 2204 (1946).

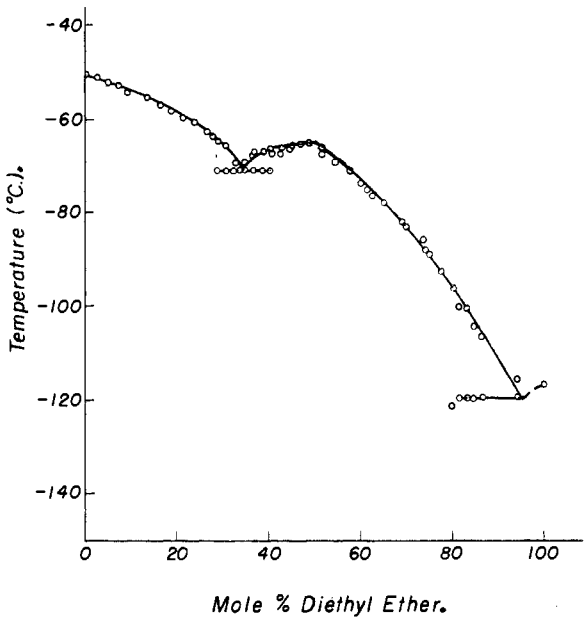

Fig. 1.—The system aluminum triethyl–ethyl ether.

DEPARTMENT OF CHEMISTRY
OHIO STATE UNIVERSITY
COLUMBUS 10, OHIO

Tetraalkyloxamides and their Reduction to N,N,-N′,N′-Tetraalkylethylenediamines[1]

BY BERNARD H. ARMBRECHT, LEONARD M. RICE, CHARLES H. GROGAN AND E. EMMET REID[2]

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In recent notes the preparation of N,N′-dialkyloxamides and their reduction to N,N′-dialkylethylenediamines have been reported.[3,4] It was shown for the first time that the adjacent carbonyls of the dialkyloxamides as well as isolated carbonyls could be reduced by lithium aluminum hydride.

It was of interest to find out whether this applied as well to the tetrasubstituted oxamides. This note deals with the preparation and reduction of several tetraalkyloxamides.

Since, as is well known, secondary amines react only slowly and incompletely with ethyl oxalate the tetraalkyloxamides were prepared from the amines and oxalyl chloride in the presence of a tertiary amine. From pyrrolidine and piperidine only tars could be obtained in spite of wide variations in operating conditions. These tars did not yield to chromatography over fluorosil. The oxamides prepared are in Table I and their reduction products in Table II.

The lithium aluminum hydride reduction of three representative tetraalkyloxamides went smoothly

(1) Supported in part by the Geschickter Fund for Medical Research, Inc.

(2) Professor Emeritus, Johns Hopkins University, Baltimore, Maryland.

(3) L. M. Rice, C. H. Grogan and E. E. Reid, THIS JOURNAL, **75**, 242 (1953).

(4) L. M. Rice, B. H. Armbrecht, C. H. Grogan and E. E. Reid, *ibid.*, **75**, 1750 (1953).

TABLE I

N,N,N',N'-TETRAALKYLOXAMIDES, $R_2NCOCONR_2$

R	Formula	B.p. °C.	Mm.	M. p., °C.	$n^{25}D$	d^{25}_4	Yield, %	Nitrogen analyses, % Calcd.	Found
Ethyl[a]	$C_{10}H_{20}N_2O_2$	148–152	10–12	45–47	....	...	75	...	...
n-Propyl[a]	$C_{14}H_{28}N_2O_2$	110–113	0.5	32–33	....	...	53	10.92	10.73
n-Butyl[b]	$C_{18}H_{36}N_2O_2$	132–135	.5	.....	1.4642	0.924	40	8.97	8.97
n-Amyl	$C_{22}H_{44}N_2O_2$	153–158	.5	.....	1.4643	.913	54	7.60	7.54
Isoamyl	$C_{22}H_{44}N_2O_2$	.....	...	51–52	....	...	75	7.60	7.93
n-Hexyl	$C_{26}H_{52}N_2O_2$	176–180	.5	.....	1.4632	.899	70	6.60	6.62
n-Heptyl	$C_{30}H_{60}N_2O_2$	193–197	.5	.....	1.4649	.892	75	5.83	5.85
Morpholino	$C_{10}H_{16}N_2O_4$	.....	...	186–188	....	...	75	12.28	12.05
Benzyl[c]	$C_{30}H_{28}N_2O_2$	.....	...	130–131	....	...	77	6.25	6.17

[a] R. Barré, *Ann. chim.*, 9, 204 (1928), reported R = ethyl, m.p., 31–32°, b.p. 142° (4 mm.); and R = propyl, m.p., 38–39°. [b] Mentioned by A. W. Campbell, U. S. Pat. 2,474,776 (June 28, 1949). [c] Recrystallized from benzene–ethanol.

TABLE II

TETRASUBSTITUTED ETHYLENEDIAMINES, $R_2NCH_2CH_2NR_2$

R	Formula	B.p. °C.	Mm.	$n^{25}D$	d^{25}_4	Yield, %	Nitrogen analyses, % Calcd.	Found	Picrate, m.p., °C.
Ethyl[a]	$C_{10}H_{24}N_2$	178–184	760	1.4330	0.799	87	16.26	15.98	240–243[b]
n-Butyl	$C_{18}H_{40}N_2$	156–158	11–13	1.4438	.808	74	9.85	10.29	185–186[c]
n-Amyl	$C_{22}H_{48}N_2$	192–194	10	1.4472	.823	80	8.23	8.31	143–144[d]
Benzyl[f,g]	$C_{30}H_{32}N_2$	.....	....	....	...	43	6.66	6.66	208–210[e]

[a] H. Gilman and R. M. Pickens, THIS JOURNAL, **47**, 245 (1925), reported b.p. 65° (8 mm.) and b.p. 70–72° (10 mm.) and a hydrochloride salt, m.p. of 187°. [b] H. R. Jones, F. A. Robinson and M. N. Straeharr, *J. Chem. Soc.*, 87 (1946), reported a m.p. of 243°. *Anal.* Calcd. for $C_{22}H_{30}N_8O_{14}$: N, 17.78. Found: N, 17.66. [c] *Anal.* Calcd. for $C_{30}H_{46}N_8O_{14}$: N, 15.09. Found: N, 14.92. [d] *Anal.* Calcd. for $C_{34}H_{54}N_8O_{14}$: N, 14.03. Found: N, 13.76. [e] *Anal.* Calcd. for $C_{42}H_{38}N_8O_{14}$: N, 12.79. Found: N, 12.87. [f] G. Lob, *Rec. trav. chim.*, **55**, 859 (1936), reported a m.p. 95°. [g] Our m.p. 93–94°.

and rapidly in ethyl ether to the corresponding tetraalkylethylenediamines. However, the tetrabenzyloxamide gave trouble on account of its slight solubility in ether. This was partially overcome by using a slurry in a mixture of tetrahydrofuran and ether. The air stability of the tetraalkylethylenediamines was greater than that observed for some of the dialkylethylenediamines.

Experimental

N,N,N',N'-Tetraalkyloxamide General Preparation.—The preparation of the tetraethyloxamide is typical. A solution of 32 g. of oxalyl chloride in 100 ml. of dry benzene was added dropwise to 37 g. of redistilled diethylamine (b.p. 54–55°) (760 mm.) and 50 g. of triethylamine in 350 ml. of benzene contained in a three-necked flask fitted with a stirrer, dropping funnel and reflux condenser protected with a calcium chloride tube. The reaction is highly exothermic and cooling was necessary. After all of the oxalyl chloride was added, the mixture was heated to reflux and filtered hot and the cake washed twice with hot benzene. The filtrate was concentrated *in vacuo* and the residue distilled. The fraction boiling at 148–152° at 10–12 mm., 38 g., solidified on cooling. This procedure was used for all except that the tetrabenzyloxamide crystallized out when the benzene solution was cooled and was purified by crystallization.

Reduction.—For the reduction a solution of 20 g. of tetraethyloxamide in 200 ml. of dry ether was added dropwise to 6 g., a 15% excess, of lithium aluminum hydride in 300 ml. of ether in a three-necked flask fitted with stirrer, dropping funnel and reflux condenser. Upon completion of the reaction (3–6 hr.) the complex was decomposed with water and the slurry filtered. The ether solution was concentrated and the residue distilled, yield 15 g., boiling 177–184°. The same procedure was used for the others except that the tetrabenzyloxamide had to be handled as a slurry and the reduction product was recrystallized.

The picrates were prepared by adding the diamine to an excess of a saturated ethanolic solution of picric acid. The mixture was refluxed for a few minutes and the picrate was filtered off from the hot mixture and washed three times with alcohol. Recrystallization from a large volume of ethanol did not raise the melting point.

GEORGETOWN UNIVERSITY MEDICAL CENTER
WASHINGTON 7, D. C.

Steroidal Cyclic Ketals. VIII.[1] $\Delta^{4,9(11)}$-Pregnadiene-17α,21-diol-3,20-dione

BY SEYMOUR BERNSTEIN, RUDDY LITTELL AND JAMES H. WILLIAMS

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In the previous paper of this series,[1] there were described several experiments with C^{11}-α- and β-hydroxy compounds under a variety of conditions. The results showed that ionic elimination reactions with either epimer gave rise to the corresponding $\Delta^{9(11)}$-steroid. Concurrent to this investigation, we devised a method for the synthesis of $\Delta^{4,9(11)}$-pregnadiene-17α,21-diol-3,20-dione (V),[2] the details of which will be presented here.

A synthesis of V was deemed highly desirable for evaluation of its biological activity, both as a mineralo- and glyco-corticoid. Moreover, this compound is of interest for a possible understanding of the enzymatic biosynthesis of C^{11}-hydroxylated steroids. On the basis that diphosphopyridine nucleotide (DPN) is required for C^{11}-β-hydroxylation by beef adrenal homogenates, Hayano and Dorfman[3] have postulated the possible transitory existence of a $\Delta^{9(11)}$- or Δ^{11}-steroid as an intermediate for hydroxylation; thus Reichstein's substance S → $\Delta^{4,9(11)}$- or $\Delta^{4,11}$-pregnadiene-17α,21-diol-3,20-dione → Reichstein's substance M (Kendall's compound F, hydrocortisone). Consequently, perfusion experiments with V would be highly significant.

A direct approach for the synthesis of this com-

(1) Paper VII, S. Bernstein, R. Lenhard and J. H. Williams, *J. Org. Chem.*, in process of publication.

(2) J. Fried and E. F. Sabo, THIS JOURNAL, **75**, 2273 (1953), have recently announced the synthesis of $\Delta^{4,9(11)}$-pregnadiene-17α,21-diol-3,20-dione 21-acetate (VI) from 11-*epi*-hydrocortisone. This publication appeared after completion of our work.

(3) M. Hayano and R. I. Dorfman, *J. Biol. Chem.*, **201**, 175 (1953).