The Structure and Chemistry of the Aldehyde Ammonias. 1-Amino-1-alkanols, 2,4,6-Trialkyl-1,3,5-hexahydrotriazines, and *N,N'*-Dialkylidene-1,1-diaminoalkanes[1]

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Reaction of aliphatic aldehydes with 15 *M* aqueous ammonia at −10 ± 15° leads instantly to very unstable, low-melting solids believed to be principally 1-amino-1-alkanol hydrates (**1a–i**). On standing in 15 *M* aqueous ammonia at 0–5° these solids are converted to 2,4,6-trialkyl-1,3,5-hexahydrotriazines (**2a–h**), usually isolated as their low-melting crystalline hydrates. Some of these triazine hydrates are the "aldehyde ammonias" prepared and described by earlier workers. Anhydrous triazines **2a–h** have been prepared; their nmr spectra and chemical behavior indicate all-equatorial 2,4,6-trialkyl substitution. Their oxidation with *tert*-butyl hypochlorite leads to 2,4,6-trialkyl-1,3,5-triazabicyclo[3.1.0]hexanes. On warming above 25° they lose ammonia rapidly to form *N,N'*-dialkylidene-1,1-diaminoalkanes (**10**); aldimines, RCH=NH, are not obtained. Pivaldehyde and 2-ethylbutanal react with 15 *M* aqueous ammonia to yield *N,N'*-dialkylidene-1,1-diaminoalkanes **10d** and **10e** and do not form stable 2,4,6-trialkyl-1,3,5-hexahydrotriazines.

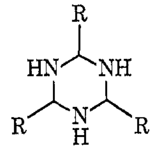
Reaction of aliphatic aldehydes with ammonia leads to the "aldehyde ammonias." The first reported, acetaldehyde ammonia, was discovered by Liebig in 1835.[3a] Preparations of many of these materials are described in the early literature (reaction temperature 0 ± 15°).[3] The substances are often isolated as colorless, unstable, low-melting solids. Considerable confusion exists regarding their structures, which, with the exception of acetaldehyde ammonia, have not been established. Most frequently they are formulated as 1-amino-1-alkanols, RCH(OH)-NH_2.[4–7] It has been shown in the present work that most of the "aldehyde ammonias" isolated and described by previous workers are 2,4,6-trialkyl-1,3,5-hexahydrotriazines or hydrates thereof.

1-Amino-1-alkanols—Aldehyde ammonias believed to be hydrates of the elusive and fugitive 1-amino-1-alkanols, precursors to the 2,4,6-tialkyl-1,3,5-hexahydrotriazines, have been prepared (**1a–i**, Table I). These were obtained by addition of aliphatic aldehydes to cold concentrated (15 *M*) aqueous ammonium hydroxide (−10 ± 15°; 5–10 min). Precipitation of the isolated products occurs instantly. Rapid filtration through a cold funnel affords white solids melting near room temperature. The nitrogen and water assays indicate the substances to be hydrates having a 1:1 ratio of aldehyde to ammonia.

$$RCHO + NH_3(aq) \rightleftharpoons \underset{\mathbf{1}}{RCH(OH)NH_2 \cdot xH_2O}$$

The materials tentatively designated 1-amino-1-alkanol hydrates **1a–i** (aldehyde ammonia hydrates) are very unstable materials, much less stable than the 2,4,6-trialkyl-1,3,5-hexahydrotriazines (*vide infra*). They readily evolve ammonia on standing. Their infrared spectra, measured at 25°, reveal aldehyde carbonyl and imine C=N bands indicating rapid dehydration and deamination; this decomposition process is slower with higher melting **1d** and **1f**. Stability and other properties vary with the alkyl substituent. Stabilities increase, and aqueous solubilities decrease, as the alkyl group increases in carbon content. Addition of isobutyraldehyde or 2-ethylbutanal to 15 *M* aqueous ammonia at −25° produced no solid; the substances formed initially are liquids at this temperature.

Conversion of **1a–i** (except **1f** from pivaldehyde) to 2,4,6-trialkyl-1,3,5-hexahydrotriazines (**2**) occurs rapidly in pyridine-d_5, as shown by examination of nmr spectra. These spectra reveal virtually no aldehyde or olefinic methine proton signals and are essentially spectra of pure **2**, indicating rapid formation of cyclic triazines in pyridine solution. In aqueous ammonia at 0° the aldehyde ammonia hydrates **1c**, **1d**, **1g**, and **1h** are observed to melt within 2 hr, forming a floating layer which more slowly changes to the corresponding crystalline triazine or hydrate thereof.



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Structures other than 1-amino-1-alkanols might be considered for the products described in Table I. The observed 1:1 ratio of aldehyde to ammonia in these substances precludes dicarbinolamines, (RCH-OH)$_2$NH, and tricarbinolamines, (RCHOH)$_3$N. The principal reason for excluding diamines, RCHOHNH-CH(R)NH_2, and acyclic or epimeric cyclic triamines is that under the reaction conditions described rates of formation of dimers and trimers are expected to be very much slower than the rate of formation of **1**.

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[3] (a) J. Liebig, *Justus Liebigs Ann. Chem.*, **14**, 133 (1835); (b) A. Waage, *Monatsh. Chem.*, **4**, 708 (1883); (c) G. Guckelberger, *Justus Liebigs Ann. Chem.*, **64**, 39 (1848); (d) A. Lipp, *ibid.*, **211**, 344, 354 (1882); (e) A. Lipp, *ibid.*, **205**, 1 (1880); (f) H. Strecker, *ibid.*, **130**, 217 (1864); (g) E. Erlenmeyer and O. Sigel, *ibid.*, **176**, 341 (1875); (h) N. N. Ljubavin, *J. Russ. Phys. Chem. Soc.*, **6**, 34 (1874); (i) C. Ebersbach, *Justus Liebigs Ann. Chem.*, **106**, 262 (1858); (j) C. F. Winans and H. Adkins, *J. Amer. Chem. Soc.*, **55**, 2051 (1933); (k) H. Schiff, *Justus Liebigs Ann. Chem. Suppl.*, **3**, 367 (1864).

[4] Y. Ogata and A. Kawasaki, *Tetrahedron*, **20**, 855, 1573 (1964).

[5] S. Coffey, Ed., "Rodd's Chemistry of Carbon Compounds," 2nd ed, Vol. 1C, Elsevier, Amsterdam, 1965, pp 41–43.

[6] J. D. Roberts and M. C. Caserio, "Basic Principles of Organic Chemistry," W. A. Benjamin, New York, N. Y., 1965, p 442.

[7] E. M. Smolin and L. Rapoport, "*s*-Triazines and Derivatives," Vol. 13 in "The Chemistry of Heterocyclic Compounds," Interscience, New York, N. Y., 1959, pp 505–509.

TABLE I

PROPERTIES OF ALDEHYDE AMMONIA HYDRATES

Compd[a]	R	Mp, °C	Yield, %	Molecular formula[b]	Nitrogen, %	
					Calcd	Found
1a	CH_3	25–28	3	$C_2H_7NO \cdot 2H_2O$	14.73	15.3
1b	C_2H_5	15–18	39	$C_3H_9NO \cdot 3H_2O$	10.85	11.3
1c	n-C_3H_7	20–22	38	$C_4H_{11}NO \cdot 3H_2O$	9.78	9.4
1d	n-C_4H_9	38–42	100	$C_5H_{13}NO \cdot 3H_2O$	8.91	8.9
1e	i-C_4H_9	25–26	63	$C_5H_{13}NO \cdot 3H_2O$	8.91	8.9
1f	t-C_4H_9	38–40	59	$C_5H_{13}NO \cdot 3H_2O$	8.91	8.8
1g	n-C_5H_{11}	15–20	55	$C_6H_{15}NO \cdot 3H_2O$	8.17	7.9
1h	n-C_6H_{13}	12–15	100	$C_7H_{17}NO \cdot 3H_2O$	7.56	7.9
1i	n-$C_{11}H_{23}$	38–42	100	$C_{12}H_{27}NO \cdot 4H_2O$	5.12	4.9

[a] Tentative structure assignment. [b] Tentative assignment based on nmr spectra and nitrogen and water assays.

This would be particularly true for the higher homologs. For example, the formation of 2,4,6-trihexyl-1,3,5-hexahydrotriazine from heptanal in aqueous ammonia in 68% yield requires a reaction time of 3 months at 0°, whereas the aldehyde ammonia hydrate **1h** is formed instantly in quantitative yield under the same conditions. Dodecanal would be expected to react even more slowly to form a dimer or trimer. Pivaldehyde, which does not produce a cyclic triazine (**2**), forms **1f** instantly. Cyclic triazines (**2**) evolve virtually no ammonia at 0° and show no infrared carbonyl band, as expected. On the other hand, 1-amino-1-alkanols could evolve ammonia rapidly at 0° and produce the observed carbonyl bands by facile retrogression to aldehyde by deamination.

The aldehyde ammonias listed in Table I appear not to have been isolated or described as such by others. Waage noted the transient formation of a white precipitate (not isolated) when ammonia was passed into a cold (*ca.* −15°) solution of propanal in petroleum ether (bp 35–100°); the precipitate liquefied on warming.[3b] In aqueous ammonia, acetaldehyde and propionaldehyde produce no precipitate at 0°; a lower temperature (−25°) is required to produce **1a** and **1b**. Butanal and isovaleraldehyde have been studied often in reactions with ammonia.[3c,e,h,4] In aqueous ammonia they form an initial white precipitate (**1c**, **1e**), but it is replaced rather rapidly by a second white precipitate of essentially identical appearance (isolated triazine polyhydrates). Heptanal has been reported to react with ammonia to produce oils.[3g,k] A known chloral ammonia, mp 62–63°, may be 2,2,2-trichloro-1-aminoethanol.[5,7–9] A few substances described as dicarbinolamines, $(RCHOH)_2NH$, have been reported, prepared at −20° by reaction of an *excess* of aldehyde with ammonia: R = CCl_3,[8,9] C_6H_5,[10] 4-$CH_3C_6H_4$.[10] Carbinolamines derived from aldehydes and ammonia, or amines, are generally quite unstable substances which may be isolated at low temperatures only in a few favorable instances.[7–15]

2,4,6-Trialkyl-1,3,5-hexahydrotriazines.—The "aldehyde ammonias" prepared by earlier workers[3,4,9] by reactions of aliphatic aldehydes with ammonia were assigned various structures. Linear monomeric, dimeric, trimeric, and polymeric carbinolamine type structures have been proposed.[3d,e,16,17] Delépine was first to suggest that acetaldehyde ammonia is 2,4,6-trimethyl-1,3,5-hexahydrotriazine trihydrate.[18] This structure was later confirmed by X-ray crystallographic studies.[19,20] No X-ray studies have been made of other aldehyde ammonias and results of attempts to elucidate their structures by chemical methods have been inconclusive.[17] A few authors have suggested that the known homologous aldehyde ammonias are 2,4,6-trialkyl-1,3,5-hexahydrotriazines.[18,21] Most frequently, however, one finds all of these substances (even acetaldehyde ammonia) described as 1-amino-1-alkanols.[3–7,22,23] Much of the earlier confusion arose because of the variable degree of hydration exhibited by these materials, and their instability. We have now prepared pure anhydrous and hydrated forms of the known aldehyde ammonias and have shown by molecular weight determinations, spectral data, and chemical behavior that they are 2,4,6-trialkyl-1,3,5-hexahydrotriazines or hydrates thereof (**2a–h**·xH_2O, R = alkyl; Table II).

Certain aldehydes having electronegative substituents have been reported to yield 2,4,6-trisubstituted 3,5-hexahydrotriazines by reaction with ammonia—compound, R: **2i**, CH_2Br;[11] **2j**, CCl_3;[5,8,9,24,25] **2k**, CF_3;[26] **2l**, CH_2OCH_3;[27] **2m**, $CH_2OC_2H_5$;[27] **2n**, 2-pyridyl;[28] **2o**, 2-(3,4-dihydro-2*H*-pyranyl).[29] Formaldehyde and ammonia are reported to react in aqueous solution to

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(8) R. Schiff, *Chem. Ber.*, **10**, 165 (1877).

(9) O. Aschan, *Chem. Ber.*, **48**, 874 (1915).

(10) F. Francis, *Chem. Ber.*, **42**, 2216 (1909).

(11) A. E. Tschitschibabin and M. N. Schtschukina, *Chem. Ber.*, **62**, 1075 (1929).

(12) L. Henry, *Bull. Acad. Roy. Belg.*, (3) **29**, 355 (1895).

(13) A. Lowy and E. H. Balz, *J. Amer. Chem. Soc.*, **43**, 341 (1921).

(14) A. Lowy and T. B. Downey, *J. Amer. Chem. Soc.*, **43**, 346 (1921).

(15) A. Hajos and P. Sohar, *Experientia*, **21**, 434 (1965).

(16) D. T. Lewis, *J. Chem. Soc.*, 968 (1939).

(17) H. H. Strain, *J. Amer. Chem. Soc.*, **54**, 1221 (1932).

(18) (a) M. Delépine, *C. R. Acad. Sci.*, **125**, 951 (1897); (b) *Bull. Soc. Chim. Fr.*, **19**, 15 (1898); (c) *C. R. Acad. Sci.*, **128**, 105 (1899); (d) *ibid.*, **144**, 853 (1907); (e) *Bull. Soc. Chim. Fr.*, **1**, 590 (1907).

(19) (a) N. F. Moerman, *Z. Kristallogr.*, **98**, 447 (1938); (b) H. Mark, *Chem. Ber.*, **57**, 1820 (1924).

(20) (a) E. W. Lund, *Acta Chem. Scand.*, **5**, 678 (1951); (b) E. W. Lund, *ibid.*, **12**, 1768 (1958).

(21) S. V. Svetozarskii, E. N. Zilberman, and A. I. Finkelshtein, *Zh. Obshch. Khim.*, **31**, 1717 (1961).

(22) R. H. Hasek, E. U. Elam, and J. C. Martin, *J. Org. Chem.*, **26**, 1822 (1961).

(23) M. M. Sprung, *Chem. Rev.*, **26**, 297 (1940).

(24) Z. El-Hewehi and F. Runge, *J. Prakt. Chem.*, **287**, 297 (1962).

(25) A. Béhal and E. Choay, *Ann. Chim. (Paris)*, **26**, 5 (1892).

(26) J. A. Young, J. J. Schmidt-Collerus, and J. A. Krimmel, *J. Org. Chem.*, **36**, 347 (1971).

(27) F. L. Johnson, Jr., U. S. Patent 3,565,895 (1971); *Chem. Abstr.*, **74**, 112060d (1971).

(28) C. Harries and G. H. Lénárt, *Justus Liebigs Ann. Chem.*, **410**, 95 (1915).

(29) H. Schulz and H. Wagner, *Angew. Chem.*, **62**, 105 (1950).

TABLE II

2,4,6-TRIALKYL-1,3,5-HEXAHYDROTRIAZINES AND HYDRATES

Compd	R	Yield, %[a]	Mp, °C	Molecular formula	Calcd, % C	H	N	Mol wt	Found, % C	H	N	Mol wt[b]
2a	CH_3		94–96[c]	$C_6H_{15}N_3$	55.77	11.70	32.53	129.20	55.30[d]	11.50[d]	32.21[d]	129
		75	94–95[e]	$C_6H_{15}N_3 \cdot 3H_2O$	39.33	11.55	22.93		39.34[f]	11.48[f]	22.95[f]	
2b	C_2H_5	89	2–3	$C_9H_{21}N_3$	63.11	12.36	24.53	171.28	63.08	12.49	24.20	180
			13–15	$C_9H_{21}N_3 \cdot 3H_2O$			18.64				18.1[g]	
2c	n-C_3H_7		6–8	$C_{12}N_{27}N_3$	67.55	12.76	19.70	213.36	67.65	12.51	19.1[g]	221
		67	28–30[h]	$C_{12}H_{27}N_3 \cdot 18H_2O$	26.81	11.81	7.82		26.74[i]	11.84[i]	7.81[i]	
2d	i-C_3H_7	78	26–27[j]	$C_{12}H_{27}N_3$	67.55	12.76	19.70	213.36	67.70	12.68	19.60	224
2e	n-C_4H_9		Oil	$C_{15}H_{33}N_3$	70.53	13.02	16.45	255.44	70.35	12.86	16.10	245
		82	16–17	$C_{15}H_{33}N_3 \cdot 3H_2O$			13.57				13.7[g]	
2f	i-C_4H_9		21–23[k]	$C_{15}H_{33}N_3$			16.45	255.44			15.5[g,k]	269
		92	59–60[l]	$C_{15}H_{33}N_3 \cdot 24H_2O$	26.19	11.87	6.11		26.2[m]	11.8[m]	6.2[g,m]	
2g	n-C_5H_{11}		−9 to −7	$C_{18}H_{39}N_3$	72.66	13.22	14.12	297.52	72.90	13.33	14.08	295
		56	15–17	$C_{18}H_{39}N_3 \cdot 3H_2O$			11.92				12.08	
2h	n-C_6H_{13}		−6 to −5	$C_{21}H_{45}N_3$	74.27	13.36	12.37	339.59	74.38	13.33	12.26	262[n]
		68	13–15	$C_{21}H_{45}N_3 \cdot 3H_2O$			10.67				10.6[g]	

[a] Yield of isolated form. [b] Determined by vapor osmometry in chloroform solvent except for **1a** (mass spectroscopy). [c] Lit. mp 95°, ref 9, 16, 18b. [d] Data of Delépine, ref 18b. [e] Lit. mp 85°,[3a] 92–93°,[4] 95°,[16] 96–98°.[9] [f] Data of Aschan, ref 9. [g] Nitrogen determination by titration of freshly prepared sample, this laboratory. [h] Lit.[4] mp 25.5–26°, 63% yield; mp 30–31°.[3d] [i] Data of Guckelberger, ref 3c. [j] Lit.[3e] mp 31°. [k] Sample contains *ca.* 20% diimine **10** (R = i-C_4H_9, $C_{15}H_{30}N_2$); see Experimental Section. [l] Lit.[3h] mp 56–58°. [m] Data of Strecker, ref 3f. [n] Partial decomposition of the sample occurs in solution at 25°.

form principally the parent 1,3,5-hexahydrotriazine (**2p**, R = H).[30–33]

Several procedures for preparation of 2,4,6-trialkyl-1,3,5-hexahydrotriazines (**2**) were examined in the present work. The most simple, effective, and general one is to add the aldehyde to 4 molar equiv of concentrated (15 *M*) aqueous ammonia at 5–10°, followed by storage at 0–5° for several days or weeks. The "aldehyde ammonias" described in the earlier literature were prepared by addition of the aldehyde to excess ice-cold concentrated ammonia, or by passing ammonia gas into the aldehyde or a solution of the aldehyde (cold) in an inert solvent such as ether. Reaction in liquid ammonia has been reported.[17] Reported procedures which employed other than aqueous ammonia often gave nitrogen-containing oils of somewhat indefinite molecular formula.[3b,g,j,k,16,17]

Two properties of the known aldehyde ammonias confused earlier attempts at structure elucidation. One is their instability causing loss of ammonia at ambient temperature; stability decreases with increasing carbon content. The other concerns the variable composition of their hydrates and the failure to recognize some of the products as hydrates. Except for acetaldehyde ammonia, earlier attempts to prepare the anhydrous compounds led to their decomposition.

Butanal and isovaleraldehyde are exceptional in forming triazine hydrates containing 18 and 24 water molecules, respectively. Triazine **2f** when added to water produces a striking effect. The hydrate forms instantly as a slightly soluble white precipitate containing water as "open ice" equal in weight to nearly twice that of the reacting triazine; on melting its water is released as a lower layer. Triazine **2c** behaves similarly. Because of the instability of these triazines this process cannot be repeated indefinitely. The water in crystalline 2,4,6-trimethyl-1,3,5-hexahydrotriazine is located in a cavity containing six water molecules.[20] In the hydrates of **2c** and **2f** the cavity must be quite large and could accommodate up to 46 water molecules.[34] Clathrate hydrates of simple amines are known.[35]

The anhydrous 2,4,6-trialkyl-1,3,5-hexahydrotriazines **2a–h** (except **2b** and **2d**) were prepared from their hydrates by several dehydration procedures. They were isolated as oils which crystallized on chilling. Further purification of some could be achieved by crystallization from isopentane at low temperature. The nmr spectra of anhydrous triazines **2a–h** in pyridine-d_5 were virtually identical with those of the corresponding hydrated forms, except for the absence of a water line and some slight chemical shifts caused by a change in solvent polarity. The anhydrous triazines, with the exception of the trimethyl compound **2a**, have melting points lower than those of the corresponding hydrates. On addition of water they reform the original hydrates. The triazines **2a–h** and their hydrates are stable as white, crystalline solids for at least several months when stored at −15°. At room temperature the anhydrous compounds are hygroscopic liquids (except **2a**) which react with the moisture and carbon dioxide of the air and slowly evolve ammonia.

Structures of the anhydrous triazines **2a–h** were established by determination of molecular weight, elemental analyses, spectra, and chemical behavior. Infrared spectra of pure samples revealed NH bands at *ca.* 3200 and 3350 cm^{-1}; no bands appeared in the double bond stretching region, indicating absence of C═C, C═O, and C═N bonds. The nmr spectra in pyridine-d_5 revealed three ring methine protons (δ 3.6–4.1) and three NH protons, usually a broad signal at δ 1–2 hidden by the alkyl proton signal; addition

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(30) P. Duden and M. Scharff, *Justus Liebigs Ann. Chem.*, **288**, 218 (1895).

(31) L. Henry, *Bull. Acad. Roy. Belg.*, 721 (1902).

(32) H. H. Richmond, G. S. Myers, and G. F Wright, *J. Amer. Chem. Soc.*, **70**, 3659 (1948).

(33) A material described as a 50% aqueous solution of 1,3,5-hexahydrotriazine is distributed by several companies and manufactured by The Ames Laboratories, Inc., 200 Rock Lane, Milford, Conn. 06460.

(34) R. M. Barrer in "Non-Stoichiometric Compounds," L. Mandelcorn, Ed., Academic Press, New York, N. Y., 1964, pp 314–315.

(35) (a) D. N. Glew, *Trans. Faraday Soc.*, **61**, 30 (1965); (b) L. Henry, *Bull. Acad. Roy. Belg.*, **27**, 448 (1893).

TABLE III

PROTON NMR SPECTRA OF ANHYDROUS 2,4,6-TRIALKYL-1,3,5-HEXAHYDROTRIAZINES. δ VALUES IN PYRIDINE-d_5 AT 30° (TETRAMETHYLSILANE INTERNAL STANDARD)

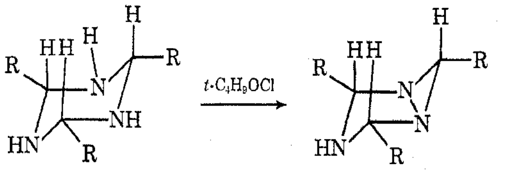
		Nmr signals, δ[a]		
Compd	Alkyl R	Ring CH	Alkyl CH, CH_2	Alkyl CH_3
2a	CH_3	3.87 q ($J \cong 6$ Hz)		1.24 d ($J \cong 6$ Hz)
2b	C_2H_5	3.64 t[b]	CH_2, 1.2–1.9 m	1.01 t[c]
2c	n-C_3H_7	3.70 t[b]	$(CH_2)_2$, 1.2–2.0 m	0.87 t[c]
2d	i-C_3H_7	3.67 d ($J \cong 6$ Hz)	CH, 1.4–2.0 m	1.18 d ($J \cong 6$ Hz)
2e	n-C_4H_9	3.96 t[b]	$(CH_2)_3$, 1.0–2.0 m	0.92 t[c]
2f	i-C_4H_9	4.14 t ($J \cong 7$ Hz)	CH, 1.7–2.5 m CH_2, 1.5–1.9 m	0.98 d ($J \cong 7$ Hz)
2g	n-C_5H_{11}	3.93 t[b]	$(CH_2)_4$, 1.0–2.0 m	0.88 t[c]
2h	n-C_6H_{13}	3.63 t[b]	$(CH_2)_5$, 1.0–2.0 m	0.83 t[c]

[a] A broad NH signal occurs at *ca.* δ 1–2 in compounds **2a–h**. Addition of D_2O produces an OH signal at δ 5.5 ± 0.5 corresponding in intensity to three exchangeable protons. [b] An apparent triplet signal which is sharpened on addition of D_2O ($J \cong 6$ Hz). These signals are broader for solutions of compounds **2e–h** containing no added D_2O. [c] An apparent triplet signal ($J \cong 6$ Hz).

of D_2O showed three readily exchangeable protons and produced a sharpening of the ring methine proton signal (Table III).

The stereochemistry of triazines **2a–h** is indicated by their relatively simple nmr spectra. In **2a**, **2b**, and **2d** sharp, clearly resolved signals are observed for ring methine and alkyl protons, indicating only one epimer having all alkyl groups equatorial. Although the spectra of **2c** and **2e–h** are not completely resolved in the alkyl region, their larger alkyl groups would also be expected to be all equatorial. These conclusions are in agreement with ^{13}C nmr spectra (to be published) and the structure of **2a** determined by X-ray crystallography.[20] In related 2,4,6-trimethyl-1,3,5-hexahydrotrioxane the all-equatorial configuration of methyl groups is favored.[36]

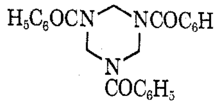
Additional evidence establishing the stereochemistry and structure of the triazines **2a–h** was obtained by their oxidation with *tert*-butyl hypochlorite in methanol (1 equiv of sodium carbonate added) at −40° to produce 2,4,6-trialkyl-1,3,5-triazabicyclo[3.1.0]hexanes **3a–h**. The triazine hydrates gave the same products. Products having cis stereochemistry of the C-2, C-4 substituents (**3a–c**) were obtained with reactants having relatively small R groups (**2a–c**, R = CH_3, C_2H_5, n-C_3H_7). Reactants having alkyl groups larger than n-C_3H_7 produced triazabicyclo[3.1.0]hexanes **3e–h** having C-2, C-4 trans stereochemistry only. These results and an alternate synthesis of **3** are discussed in detail elsewhere.[37-39]



2a–c

cis-**3a**, R = CH_3
cis-**3b**, R = C_2H_5
cis-**3c**, R = n-C_3H_7

Few reactions of the 2,4,6-trialkyl-1,3,5-hexahydrotriazines (other than **2** → **3**) leave the original triazine ring intact. Several N-substituted derivatives of 1,3,5-hexahydrotriazine itself are known and a few of these have been prepared from aqueous solutions believed to contain this compound. For example, benzoyl chloride yields the trisbenzoyl deriative **4** in 13% yield,[30,32] and nitrous acid yields the trinitroso compound **5a** in 52% yield.[32] Although 2,4,6-trimethyl-1,3,5-hexahydrotriazine (**2a**) reacts with nitrous acid to provide a 5% yield of the trinitroso derivative **5b**,[18d,e] reaction with benzoyl chloride under a variety of conditions failed to yield a 1,3,5-trisbenzoyl derivative of **2a**. The product was *N*,*N*-dibenzoyl-1,1-diaminoethane (**6**), in agreement with earlier findings.[40,41] Reaction of anhydrous **2a** with 1 molar equiv of phenyl isocyanate in tetrahydrofuran gave the bisurea **7** rather than the 1,3,5-triphenylcarbamoyl derivative of **2a**.



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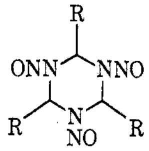


5a, R = H
b, R = CH_3

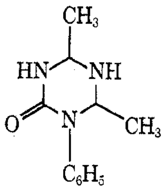
$$C_6H_5CONH\underset{\displaystyle CH_3}{\underset{|}{C}}HNHCOC_6H_5$$

6

$$C_6H_5NHCONH\underset{\displaystyle CH_3}{\underset{|}{C}}HNHCONHC_6H_5$$

7

Known **7** has been synthesized from acetaldehyde and phenylurea.[42] Phenyl isocyanate has been reported to react with an *excess* of **2a** in ether to form 2,4-dimethyl-6-oxo-1-phenyl-1,3,5-hexahydrotriazine (**8**).[43]



8

The scope and limitations of the reaction of aldehydes with ammonia to yield 2,4,6-trisubstituted 1,3,5-hexahydrotriazines (of sufficient stability to permit

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(36) E. L. Eliel and M. C. Knoeber, *J. Amer. Chem. Soc.*, **90**, 3444 (1968).

(37) E. Schmitz and R. Ohme, *Chem. Ber.*, **95**, 795 (1962).

(38) A. T. Nielsen, R. L. Atkins, D. W. Moore, D. Mallory, and J. M. La Berge, *Tetrahedron Lett.*, 1167 (1973); *J. Org. Chem.*, forthcoming publication.

(39) R. L. Atkins, D. W. Moore, D. Mallory, J. M. La Berge, and A. T. Nielsen, Abstracts, 165th National Meeting of the American Chemical Society, Dallas, Texas, April 1973, Paper No. C-63.

(40) K. Kraut and Y. Schwartz, *Justus Liebigs Ann. Chem.*, **223**, 40 (1884).

(41) H. Limpricht, *Justus Liebigs Ann. Chem.*, **99**, 117 (1856).

(42) R. G. Fargher, *J. Chem. Soc.*, **117**, 668 (1920).

(43) A. E. Dixon, *J. Chem. Soc.*, **61**, 509 (1892).

TABLE IV

PROTON NMR SPECTRA OF *N*,*N'*-DIALKYLIDENE-1,1-DIAMINOALKANES, $RCH(N{=}CHR)_2$. δ VALUES IN DEUTERIOCHLOROFORM AT 30° (TETRAMETHYLSILANE INTERNAL STANDARD)

		Methine signals		Alkyl signals	
Compd	R	Imino RCH=N	Alkyl CHR	Alkylidene RCH=	Alkyl CHR
10a	CH_3	7.82 (J = 4.5 Hz)[a,b]	4.50 q (J = 6 Hz)[a]	CH_3, 1.98 d (J = 4.5 Hz)[a]	CH_3, 1.37 d (J = 6 Hz)[a]
10b	C_2H_5	7.72 t[b] (J = 4.5 Hz)	4.17 t[c] (J = 6 Hz)	CH_3, 1.10 t (J = 7 Hz) CH_2, 2.2–2.8 m	CH_3, 0.98 t (J = 7 Hz) CH_2, 1.4–2.0 m
10c	*i*-C_3H_7	7.58 d[b] (J = 4.5 Hz)	3.92 d (J = 6 Hz)	CH_3, 1.10 d (J = 7 Hz) CH, 2.2–2.8 m	CH_3, 0.97 d (J = 7 Hz) CH, 1.6–2.2 m
10d (cis,trans)	*t*-C_4H_9	7.52 s[b]	3.83 s[c]	CH_3, 1.09 s	CH_3, 0.90 s
10d (trans,trans)	*t*-C_4H_9	7.52 s[b]	3.83 s[c]	CH_3, 1.09 s	CH_3, 0.88 s
10e	$(C_2H_5)_2CH$	7.50 d[b] (J = 6 Hz)	4.32 d (J = 3.5 Hz)	CH_3, 0.89 t[d] CH_2, 1.2–1.7 m CH, 1.8–2.3 m	CH_3, 0.90 t[d] CH_2, 1.2–1.7 m CH, 1.2–1.8 m[e]

[a] Caprio, *et al.*, report δ 7.6 q (J = 4.5 Hz), 4.3 q (J = 6 Hz), 1.9 d (J = 4.5 Hz), 1.2 d (J = 6 Hz) in carbon tetrachloride (ref 44). [b] Signals split to doublet ($J \cong 1$ Hz). [c] Signals split to triplet ($J \cong 1$ Hz). [d] Apparent triplet, $J \cong 7$ Hz). [e] Signal obscured by the CH_2 signal.

their isolation and storage) may now be defined. With *n*-alkanals the reaction succeeds with all those examined (through heptanal). The reaction is much slower with heptanal than with acetaldehyde, and the heptanal-derived triazine product (**2h**) is less stable than **2a**. These observations agree with the conclusions of Ogata and Kawasaki on the kinetics of the reaction of aldehydes with ammonia: electron-releasing groups were found to decrease the forward rate and increase the reverse rate of the reaction.[4] (These authors did not recognize their products as triazines.) Alkyl-substituted alkanals having substituent in the β–ω positions should undergo the reaction; isovaleraldehyde forms triazine **2f** readily. Electronegatively substituted aldehydes such as chloral react with ammonia easily, forming rather stable substituted hexahydrotriazines.[8,9,11,24–29] Isobutyraldehyde is the only α-branched alkyl-substituted alkanal observed to produce a stable triazine (**2d**). Pivaldehyde and 2-ethylbutanal failed to yield isolable triazines; the products are principally *N*,*N'*-dialkylidene-1,1-diaminoalkanes. The reaction also fails with aryl carboxaldehydes such as benzaldehyde and furfural, the products being hydrobenzamide types $[ArCH(N{=}CHAr)_2]$.[10,23] A product described as 2,4,6-triphenyl-1,3,5-hexahydrotriazine is believed to be hydrobenzamide.[21]

***N*,*N'*-Dialkylidene-1,1-diaminoalkanes and Other Products.**—On gentle heating (40–80°) the 2,4,6-trialkyl-1,3,5-hexahydrotriazines **2a–h** readily lose ammonia to produce *N*,*N'*-dialkylidene-1,1-diaminoalkanes **10** (hydracetamides) in high yield. Nmr spectra support the assigned structures (Table IV). The reaction is reversible. Excess ammonia reacts with the diimines to regenerate the cyclic triazines. These reactions are believed to involve the acyclic triamine intermediate **9**.

$$\mathbf{2a\text{–}h} \rightleftarrows \underset{\mathbf{9}}{[RCH(NH_2)NHCH(R)N{=}CHR]} \underset{NH_3}{\overset{-NH_3}{\rightleftarrows}} \underset{\mathbf{10}}{RCH(N{=}CHR)_2}$$

Stability of diimines **10** varies with substituent R. The trimethyl compound **10a** (R = CH_3; hydracetamide itself) is a liquid (mp −5°) which polymerizes readily.[44] (Yellow solids, previously referred to as hydracetamide, may contain polymers of **10a**.[17,45,46]) Diimines with small *n*-alkyl groups (**10a**, **10b**) polymerize extremely readily on heating. Polymerization during preparation may be diminished by heating the reactant triazine at reflux as a dilute solution (*ca.* 1%) in an inert solvent such as hexane; the triethyl compound **10b** was prepared in this manner in 80% yield. Diimines containing alkyl groups with α branching [*i*-C_3H_7, *t*-C_4H_9, $(C_2H_5)_2CH$, etc.] are rather stable. *N*,*N'*-Diisobutylidene-1,1-diamino-2-methylpropane (**10c**) was prepared in 87% yield by distillation of the neat triazine **2d** at 12 mm. Several diimines having α-branched R groups, including **10c**, have been reported.[22] These were prepared by distillation of the oily product obtained by reaction of aldehydes with concentrated aqueous ammonia; the corresponding triazines were not isolated.[22] Our findings indicate that these undistilled crude products contain principally diimine **10**.

Diimines **10d** and **10e** were isolated as products of reaction of concentrated aqueous ammonia with pivaldehyde and 2-ethylbutanal, respectively. Examination of the nmr spectra of the crude, undistilled reaction products reveals absence of a triazine ring CH signal near δ 4; the spectra are virtually identical with those of the pure diimines. Two geometrical isomers of **10d** were isolated. In methanolic ammonia at −15° pivaldehyde produced a thermodynamically less stable isomer, mp 72–73° (70% yield). In methanol or chloroform solution at 25° it isomerized rapidly to the more stable form obtained by reaction in aqueous ammonia at 5° (mp 28–29°). This isomerization was followed in the nmr spectrum, which for the less stable form (assigned a cis,trans structure) reveals a methyl singlet at δ 0.90 that rapidly disappears,

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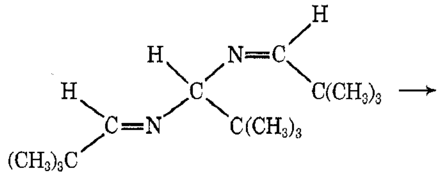
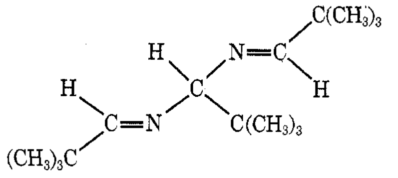
(44) V. Caprio, A. Di Lorenzo, and G. Russo, *Chim. Ind. (Milan)*, **50**, 898 (1968); *Chem. Abstr.*, **70**, 4070 (1969).

(45) H. Schiff, *Justus Liebigs Ann. Chem. Suppl.*, **6**, 1 (1868).

(46) H. Strecker *Justus Liebigs Ann. Chem. Suppl.*, **6**, 255 (1868).



cis,trans-**10d**



trans,trans-**10d**

leading to the methyl signal (δ 0.88) of the more stable form (assigned a trans,trans structure), Table IV.

An erroneous notion persists that unsubstituted alkylidene imines (**11**, R = alkyl) may be *synthesized*

$$\underset{\mathbf{1}}{\mathrm{RCH(OH)NH_2}} \rightleftarrows \underset{\mathbf{11}}{\mathrm{RCH{=}NH}} + \mathrm{H_2O}$$

by pyrolysis of "aldehyde ammonias."[5,17,18,23,47,48] Although such imines would be expected to form by dehydration of 1-amino-1-alkanols (**1**), pure alkylidene imines of this type have never been isolated. Self-reaction of pure **11** occurs too rapidly to permit isolation, and pyrolysis of 2,4,6-trialkyl-1,3,5-hexahydrotriazines (**2**) takes a different reaction course. At 100–350° 2,4,6-trimethyl,1,3,5-hexahydrotriazine (**2a**) initially yields diimine **10a**, which dissociates to *N*-vinylethylideneimine (**12a**, R = CH_3; R′ = R″ = H).[44,48] Diimines having α-branched R groups behave similarly at 250°, producing high yields of *N*-vinylimines (**12**) and nitriles.[22] Aldimines produced

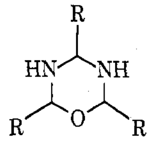
$$\mathbf{2} \xrightarrow[-\mathrm{NH_3}]{250^\circ} \mathbf{10} \xrightarrow{250^\circ} \underset{\mathbf{12}}{\mathrm{R'R''C{=}CHN{=}CHR}} + \mathrm{RCN}$$

by pyrolysis of 2,4,6-trialkyl-1,3,5-hexahydrotriazines must be present at very low equilibrium concentrations.[44] Attempts to isolate them lead to regenerated triazines (**2**),[44] diimines (**10**),[22,44] vinylimines (**12**),[22,48] or polymers. In this respect aldimine trimers (**2**) differ from aldehyde trimers (2,4,6-trialkyl-1,3,5-hexahydrotrioxanes), which geneate isolable aldehydes on pyrolysis. Formation of alkylidene imines by photolysis of alkyl azides has been reported.[49] However, these imines were not characterized by molecular formula or spectra; their presence was inferred by isolation of the corresponding aldehyde 2,4-dinitrophenylhydrazone derivatives.[49] N-Substituted imines are more stable than those bearing an NH group.[23,48–54]

A mechanism of 2,4,6-trialkyl-1,3,5-hexahydrotriazine formation from 1-amino-1-alkanol (**1**) reasonably involves alkylidene imine **11**, acyclic dimer **13**, and trimer **9**. Other possible intermediates could include covalent hydrates of **9** and **13** [*e.g.*, RCH(OH)NHCH(NH_2)R].

$$\mathbf{1} \longrightarrow \underset{\mathbf{11}}{\mathrm{RCH{=}NH}} \xrightarrow{\mathbf{11}} \underset{\mathbf{13}}{\mathrm{RCH{=}NCH(NH_2)R}} \xrightarrow{\mathbf{11}} \mathbf{9} \rightleftarrows \mathbf{2}$$

Stable products in addition to diimines **10** and triazines **2** are suspected in the reaction of aldehydes with ammonia. Formation of pure higher molecular weight triazines **2g** and **2h** occurs slowly in aqueous ammonia. Products isolated at intermediate reaction times are relatively lower melting and have lower nitrogen content. In addition to the NCHN proton nmr peak near δ 4.0, their spectra usually reveal an extraneous peak (broad triplet near δ 4.5, $CDCl_3$ or pyridine-d_5 solvent) assigned to an NCHO proton.[55] Diimine is not the impurity in these samples, since a vinyl methine signal near δ 7.5 is absent. A relatively low value of the total number of exchangeable protons (as determined by addition of D_2O) excludes large amounts of amino alcohol impurities. It is suggested that the contaminants in these samples are 2,4,6-trialkyl-1,3,5-hexahydrooxadiazines (**14**, R =



14

alkyl). Synthetic routes to pure **14** are under investigation.

Experimental Section[56]

Aldehydes.—All aldehydes employed were commercial samples, reagent grade, distilled immediately before use.

Preparation of Aldehyde Ammonia Hydrates (1a–i).—The general procedure may be illustrated with the preparation of **1b**. Propanal (5.8 g, 0.1 mol) was added dropwise with stirring during 10 min to concentrated (15 *M*) aqueous ammonium hydroxide (27 ml, 0.4 mol), keeping the temperature of the solution at −25° by external cooling (Dry Ice–ethylene dichloride bath). A white precipitate appeared instantly on addition of the aldehyde to the cold ammonia solution. Stirring was continued for 5 min with the temperature of the reaction mixture maintained at −25°. The product was filtered immediately with suction through a cold (−18°) jacketed sintered glass Buchner funnel, protected with a calcium chloride tube, to yield 5.0 g (39%) of **1b**, mp 15–18°. A 1.0-g aliquot of the product (removed and weighed very rapidly) was treated immediately with 25.0 ml of 1 *N* hydrochloric acid; titration with 1 *N* sodium hydroxide neutralized the excess acid (methyl red indicator); see Table I for nitrogen analysis. The product decomposed rapidly with evolution of ammonia on standing in the funnel at −18° (no suction) and within 45 min became mushy and partly liquefied.

Aldehyde ammonia hydrates **1a**, **1e**, **1g**, and **1h** were prepared (0.1-mol scale) by the procedure described above for **1b** (reaction temperature −25°) except that preparation of **1a** employed 0.44 mol of aldehyde and a 30-min addition time. Other aldehyde ammonia hydrates were prepared on a 0.1-mol scale under the conditions used for **1b** except for different reaction temperatures as follows: **1c**, −10°; **1d**, −15°; **1f**, 6°; **1i**, 3°. Properties of the aldehyde ammonia hydrates are summarized in Table I. To obtain products having the properties described requires careful

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(47) P. A. S. Smith, "The Chemistry of Open-Chain Organic Nitrogen Compounds," Vol. I, W. A. Benjamin, New York, N. Y., 1965, p 326.

(48) J. Meir, F. Akerman, and H. H. Günthard, *Helv. Chim. Acta*, **51**, 1686 (1968).

(49) D. H. R. Barton and L. R. Morgan, Jr., *J. Chem. Soc.*, 622 (1962).

(50) B. Mauzé, J. Pornet, M.-L. Martin, and L. Miginiac, *C. R. Acad. Sci., Ser. C*, **270**, 562 (1970).

(51) Reference 7, pp 476–489.

(52) J. Hinze and R. F. Curl, Jr., *J. Amer. Chem. Soc.*, **86**, 5068 (1964).

(53) G. B. Carter, M. C. McIvor, and R. G. J. Miller, *J. Chem. Soc. C*, 2591 (1968).

(54) J. Hine and F. A. Via, *J. Amer. Chem. Soc.*, **94**, 190 (1972).

(55) L. C. Dorman, *J. Org. Chem.*, **32**, 255 (1967).

(56) Infrared spectra were determined on a Perkin-Elmer Model 137 spectrophotometer, nmr spectra on a Varian A-60 spectrometer, and mass spectra on a Hitachi Model RMU-6E. Elemental analyses were performed by Galbraith Laboratories, Knoxville, Tenn., unless otherwise noted.

adherence to the reaction conditions and procedures specified. Higher molecular weight alkanals such as hexanal produce instant precipitates at 0–5° or at lower temperatures. Acetaldehyde and propanal yield precipitates only at −25°; at higher temperatures they produce only clear solutions. The product (**1a**) derived from acetaldehyde is very unstable (half-life *ca.* 10 min at −18°) and very soluble in aqueous ammonia; it could be isolated only in low yield. Products derived from butanal and higher alkanals (**1c–i**) may be isolated in good yield and are relatively much more stable (half-lives of *ca.* 0.5–1 hr at 0°). Some products were washed with aqueous ammonia and/or ether prior to assay without affecting the analytical results significantly. Since products are quite unstable all samples were stored in the cold funnel (−18°, without suction) and analyzed very rapidly.

Chemical Behavior and Spectra of Aldehyde Ammonia Hydrates (1a–i).—A sample of **1a** when warmed rapidly from −18 to 25° melted and then solidified almost instantly to produce 2,4,6-trimethyl-1,3,5-hexahydrotriazine trihydrate (**2a**), mp 84–87° (identified by infrared and nmr spectra and mixture melting point determination with authentic sample). A sample of **1e**, derived from isovaleraldehyde, increased its melting point on standing at −18°. After 1 hr the melting point was 30–35° and its infrared spectrum, which now revealed no carbonyl absorption, was like that of the triazine **2f** (probably a different hydrate from one prepared by a different procedure which contains 24 water molecules; see below).

Nmr spectra of **1a–i** determined in pyridine-d_5 solvent were virtually identical with those of pure 2,4,6-trialkyl-1,3,5-hexahydrotriazines **2a–h** (Table III) in aqueous pyridine-d_5 and revealed a very strong water peak near δ 4.5–5. No aldehyde or vinyl CH signals were observed. The integrals of the water signals (relative to the ring CH and alkyl signal integrals) and the nitrogen analyses of **1a–i** indicate a molecular formula corresponding to a 1:1 adduct of aldehyde and ammonia with two to four molecules of water of hydration. The water assays and nitrogen analyses varied slightly in parallel runs and with the age of the sample. Water assays could also be roughly determined by diluting weighed samples with isopentane and measuring the volume of the lower water layer, or by adding anhydrous magnesium sulfate to the isopentane solution and determining the gain in weight of the hydrated sulfate after filtration and washing with isopentane (see procedure under preparation of **2c**, below). The infrared spectra of **1a–i** were determined at 25° on fresh samples (rapidly prepared Nujol mull or KBr disk) and scanning the spectrum as rapidly as possible. Spectra were all similar in showing very strong NH and OH bands near 3400 cm^{-1} and carbonyl and C=N bands near 1720 and 1650 cm^{-1}, respectively. The product of highest melting point (**1d**), derived from pentanal, produced an infrared spectrum (mull) showing very strong OH and NH bands and relatively weak C=O and C=N bands. On standing at 25°, the C=O and C=N band intensities rapidly increased.

2,4,6-Trialkyl-1,3,5-hexahydrotriazines (2a–h).—These were prepared by addition of aldehydes to 4 molar equiv of 15 *M* concentrated aqueous ammonia at 0–5° followed by storage at 0°. Nitrogen analyses by titration, and water assays of hydrates of **2a–h**, were determined by the methods described above for **1a–i**; data are summarized in Table II. Proton nmr spectra of triazines **2a–h** are summarized in Table III.

2,4,6-Trimethyl-1,3,5-hexahydrotriazine trihydrate (2a trihydrate) was prepared by the procedure of Aschan,[9] 75% yield, mp 94–95°. A sample of "acetaldehyde ammonia," mp 92–95°, supplied by Aldrich Chemical Co., had properties identical with those of **2a** trihydrate. The anhydrous form (**2a**) was prepared by drying at ambient temperature in a vacuum desiccator over calcium chloride, mp 94–96°.

2,4,6-Triethyl-1,3,5-hexahydrotriazine (2b).—Propanal (58.2 g, 1.0 mol) was added to concentrated (15 *M*) aqueous ammonium hydroxide (266 ml, 4.0 mol) during 10 min, keeping the temperature below 5° (ice-bath cooling). No precipitate was observed during this time. The clear, homogeneous solution was stored at 0° for 5 days. Sodium chloride (80 g) was added and the mixture was stirred at room temperature for 1 hr, then extracted with four 100-ml portions of ether. The combined ether extracts were dried with magnesium sulfate, filtered, and concentrated under reduced pressure and then pumped at 0.1 mm for 1 hr to yield 57.0 g of crude **2b**, mp 0–3° (temperature maintained below 25° during work-up). The crude product was dissolved in ether and stirred with Drierite for 5 min, filtered, and concentrated to yield 50.6 g (89%) of **2b**, mp 2–3° (analytical sample). The product could be distilled, bp 55–60° (10 mm), but with decomposition to yield a mixture of **2b** and diimine **10b** (*ca.* $^2/_3$ **2b** by nmr assay).

Addition of 3 molar equiv of water to a sample of anhydrous **2b** produced its trihydrate on chilling, mp 13–15°. Addition of 1 molar equiv of water gave a solution which did not crystallize at −15°, and addition of 18 molar equiv of water gave crystals, mp 4–5°. These hydrates are soluble in 15 *M* aqueous ammonium hydroxide at 0°.

2,4,6-Tripropyl-1,3,5-hexahydrotriazine (2c).—Butanal (36.0 g, 0.5 mol) was added to concentrated (15 *M*) aqueous ammonium hydroxide (133 ml, 2.0 mol) with stirring during 15 min (5–10°). A white precipitate of aldehyde ammonia **1c** formed immediately on addition of the aldehyde. After *ca.* 90 min storage at 0° this initial precipitate had changed to a floating oily layer. Storage at 0° for 8 days gave a large amount of crystals mixed with some oil. The mixture was filtered through a jacketed (−6°) sintered glass Buchner funnel and washed successively with cold 15 *M* ammonia, ice water, and cold isopentane to yield 59.9 g (67%) of **2b** octadecahydrate, mp 28–30°. Shorter reaction times gave lower yields: 4 days, 58%; 1 day, 36%. On melting, the hydrate produced two liquid layers which resolidified on chilling, mp 28–30°. A 2.0-g sample of the hydrate in 25 ml of methylene chloride was stirred with magnesium sulfate (3.00 g) for 1 hr to yield 4.22 g of magnesium sulfate hydrate after filtration and washing with methylene chloride; the gain in weight of the sulfate corresponds to 18.5 molar equiv of water of hydration. The nmr spectrum of the hydrate (pyridine-d_5) showed δ 5.10 (s, 40, 18.5 H_2O and 3 NH), 3.88 (t, $J \cong 6$ Hz, 3, CH), 1.2–2.0 (m, 12, CH_2CH_2), 0.96 (t, $J = 6$ Hz, 9, CH_3).

A 7.5-g sample of the hydrate at 0° was pumped at 0.05 mm for 18 hr to yield 2.6 g (90%) of crude anhydrous triazine **2c**; purification was achieved by dissolving in isopentane and drying with Drierite for 10 min; filtration, followed by concentration at 25° and pumping at 0.1 mm for 10 min, gave pure **2c**, mp 6–8°. Addition of excess water to anhydrous **2c** regenerated the hydrate, mp 24–28°.

2,4,6-Triisopropyl-1,3,5-hexahydrotriazine (2d).—The procedure employed in preparation of **2c** was used (0.5 mol of isobutyraldehyde). A floating oily layer formed during the addition, but no solid was observed. After storage at 0° for 24 hr, crystals which had formed were removed by filtration through the cold funnel and washed with ice water to yield 31.0 g of slightly wet **2d** as white crystals, mp 21–22°; the nmr spectrum (pyridine-d_5) revealed no water peak near δ 5; addition of D_2O to the sample produced a water peak at δ 5.62 corresponding to *ca.* four protons (3 NH and *ca.* 0.5 H_2O); reaction of a 2.00-g sample with 3.00 g of anhydrous magnesium sulfate (as with **2c**) produced a weight gain of only 0.02 g. A 3.0-g aliquot dissolved in 30 ml of isopentane to produce a slightly turbid solution, but no water layer; the solution was dried as with **2c** to yield 2.7 g (78%) of pure **2d**, mp 26–27°.

2,4,6-Triisobutyl-1,3,5-hexahydrotriazine (2f).—The procedure employed for preparation of **2c** was used (0.5 mole of isovaleraldehyde; 10 min addition time). A precipitate of isovaleraldehyde ammonia hydrate (**1e**) formed immediately on addition of the aldehyde to the ammonia; on storage at 0° no liquefaction of the initial precipitate was observed (as in the preparations of **2c** and **2e**); a white precipitate was present during the entire period of storage at 0° (1 month). The crystals were removed by filtration and washed with ice water to yield 63.5 g (92%) of **2f** hydrate (24 H_2O), mp 58–60°. The nmr spectrum of the hydrate (pyridine-d_5) showed δ 5.18 (s, 51, 24 H_2O and 3 NH), 4.00, (t, $J \cong 6$ Hz, 3, ring CH), 1.7–2.3 (m, 3, isopropyl CH), 1.4–1.8 (m, 6, CH_2), 0.92 (d, $J = 6$ Hz, 18, CH_3). A 20.0-g sample of the hydrate was melted by gentle heating in a water bath to yield two layers, and the water layer (*ca.* 12 ml) was removed with a pipette. The remaining liquid was dissolved in 50 ml of isopentane, dried with Drierite, and purified as described for **2c** to yield 7.5 g of crude triazine **2f**, mp 21–23°. Some decomposition occurred during the dehydration process leading to a product having some C=N, but no C=O, absorption in the infrared spectrum (1650 cm^{-1}); the nmr spectrum revealed triplet signals at δ 4.9 and 7.8, characteristic of a diimine (**10**, R = i-C_4H_9), which are absent in the hydrate. Other methods of dehydration, including pumping at 0° (0.05 mm) and drying in isopentane at 25°, also produced samples of triazine **2f** containing some diimine **10** (*ca.* 20% by nmr assay and titration; see Table II). Addition of water to **2f** regenerated the hydrate (24 H_2O), purified by filtration and washing with isopentane.

2,4,6-Trialkyl-1,3,5-hexahydrotriazines 2e, 2g, 2h and their hydrates were prepared by the procedure employed for **2c** except for reaction times of 18 days for **2e** and 3 months for **2g** and **2h**.

***N,N'*-Bis(2-ethylbutylidene)-2-ethyl-1,1'-diaminobutane (10e).**—2-Ethylbutanal (50.1 g, 0.5 mol) was added, with stirring, to concentrated (15 *M*) aqueous ammonium hydroxide (133 ml, 2.0 mol) during 3 min (reaction temperature 5–6°) to produce an oil. The mixture was stored at 0°; small aliquots were removed from the floating oily layer at intervals to determine infrared and nmr spectra. During 2 weeks the aldehyde carbonyl band at 1720 cm^{-1} slowly disappeared while the C=N band at 1650 cm^{-1} increased in intensity. After 2 weeks the oily product revealed an nmr spectrum virtually identical with that of pure **10e**; no proton signal was observed near δ 4 characteristic of 2,4,6-trialkyl-1,3,5-hexahydrotriazines. After 3 months' storage at 0° the oil was separated (virtually no change in nmr or ir spectra from that observed at 2 weeks); the aqueous layer was extracted with hexane; and the oil and combined hexane extracts were dried with Drierite. Distillation produced 3.8 g, bp 40–60° (5–13 mm), containing some 2-ethylbutanal (C=O band at 1725 cm^{-1}), and 37.9 g (81%) of **10e**: bp 107–110° (3 mm); $n^{25}\text{D}$ 1.4543; ν (neat) 1670 cm^{-1} (C=N), carbonyl bands absent; nmr data in Table IV.

Anal. Calcd for $C_{18}H_{36}N_2$: C, 77.07; H, 12.94; N, 9.99; mol wt, 280.5. Found: C, 77.18; H, 13.04; N, 9.86 (Dumas), 9.78 (titration); mol wt, 278 (osmometry, chloroform).

***cis,trans-N,N'*-Bis(2,2-dimethylpropylidene)-2,2-dimethyl-1,1-propanediamine (*cis,trans*-10d).**—Pivaldehyde (8.6 g, 0.10 mol) was dissolved in 9.7 *M* methanolic ammonia (40 ml, 0.40 mol) and stored at −15°; within 20 min a precipitate began to form. After 5 days at −15° the product was filtered through a cold-jacketed funnel and washed with cold (−15°) methanol to yield 5.6 g (70%) of *cis,trans*-**10d** as large, colorless rectangular prisms, mp 72–73°, ν (KBr) 1650 cm^{-1} (C=N), nmr data in Table IV.

Anal. Calcd for $C_{15}H_{30}N_2$: C, 75.56; H, 12.68; N, 11.75; mol wt, 238.4. Found: C, 75.65; H, 12.72; N, 11.68; mol wt, 243 (osmometry, chloroform).

Isovaleraldehyde, hexanal, heptanal, and 2-ethylbutanal were treated with *ca.* 10 *M* methanolic ammonia in procedures similar to that used with pivaldehyde (3–30 days' reaction time). Products isolated were oils at ambient temperature and contained principally the same compounds produced with 15 *M* aqueous ammonia as a reactant.

***trans,trans-N,N'*-Bis(2,2-dimethylpropylidene)-2,2-dimethyl-1,1-propanediamine (*trans,trans*-10d).**—Pivaldehyde (43.1 g, 0.5 mol) was added dropwise with stirring to 15 *M* aqueous ammonia (133 ml, 2.0 mol) during 5 min (6–8°). Within *ca.* 10 min at 0° a voluminous white precipitate (mp 45–48°) was produced. After standing with the aqueous ammonia at 25° for 4 hr the precipitate had changed to an oil. Continued storage at 0° for 6 days produced white crystals, 32 g of crude product, mp 20–22°; it was dissolved in isopentane and dried with Drierite to yield 24.6 g, mp 24–28°, found 13.1% N by titration. Distillation gave 22 g (55%) of *trans,trans*-**10d**: bp 78° (9 mm); mp 28–29°; ir (neat liquid) 1650 cm^{-1} (C=N); the ir spectrum was practically identical with that observed for *cis,trans*-**10d**.

Anal. Calcd for $C_{15}H_{30}N_2$: C, 75.56; N, 12.68; N, 11.75; mol wt, 238.4. Found: C, 74.63; H, 12.55; N, 11.63 (Dumas), 11.77 (titration); mol wt, 250 (osmometry, chloroform).

***N,N'*-Dipropylidene-1,1-diaminopropane (10b).**—2,4,6-Triethyl-1,3,5-hexahydrotriazine (**2b**) (10 g, 0.0584 mol) dissolved in 1 l. of hexane was heated under reflux for 7 hr. The solution was concentrated and the residue was distilled to yield 7.2 g (80%) of colorless **10b**: bp 48–50° (5 mm); $n^{25}\text{D}$ 1.4465; $d^{25}{}_4$ 0.857; ir (neat) 1650 cm^{-1} (C=N); nmr, Table IV; 1.5 g of yellow residue remained. The distillate polymerized and became viscous on standing. A freshly distilled sample was employed immediately for analysis.

Anal. Calcd for $C_9H_{18}N_2$: N, 18.16. Found: N, 18.3 (titration).

The procedure used for preparation of **10b** was repeated with 2,4,6-trimethyl-1,3,5-hexahydrotriazine (**2a**) (18-hr reflux) to yield, after removal of the hexane by distillation, an oil containing *ca.* 10% of recovered **2a** and 90% of *N,N'*-bisethylidene-1,1'-diaminoethane (**10a**) (nmr assay; Table IV). The product polymerized rapidly on standing and/or heating.[44] The procedure was also repeated with 2,4,6-triisobutyl-1,3,5-hexahydrotriazine (**2f**) (reflux time 4 hr) to yield a fraction, bp 100–111° (3 mm), containing unidentified impurities and *N,N'*-diisobutylidene-1,1-diamino-3-methylbutane, nmr ($CDCl_3$) δ 7.72 t (J = 4.5 Hz, CH=N), 4.25 t (J = 6 Hz, CH).

***N,N'*-Diisobutylidene-1,1-diamino-3-methylpropane (10c).**—2,4,6-Triisopropyl-1,3,5-hexahydrotriazine (**2d**) (10.0 g, 0.047 mol) was distilled through a short Vigreux column to yield 8.0 g (87%) of **10c**: bp 78–80° (12 mm); $n^{25}\text{D}$ 1.4375 (lit.[22] $n^{20}\text{D}$ 1.4391); $d^{25}{}_4$ 0.830; ir (neat) 1650 cm^{-1} (C=N); nmr, Table IV. Vigorous evolution of ammonia occurred during the initial heating.

Anal. Calcd for $C_{12}H_{24}N_2$: C, 73.41; H, 12.32; N, 14.27; mol wt, 196.3. Found: C, 73.23; H, 12.26; N, 14.13; mol wt, 200 (osmometry, chloroform).

A mixture of 3.92 g (0.02 mol) of **10c** and 16 ml of 15 *M* aqueous ammonia was stored at 0° for 1 week to yield 4.0 g (94%) of 2,4,6-triisopropyl-1,3,5-hexahydrotriazine (**2d**), mp 20–22° (identified by ir and nmr spectra and mixture melting point with an authentic sample).

***N,N'*-Dibenzoyl-1,1-diaminoethane (6).**—2,4,6-Trimethyl-1,3,5-hexahydrotriazine trihydrate (1.84 g, 0.01 mol) was added to 5 ml of ethanol and 14 ml of 10% aqueous sodium hydroxide solution. Benzoyl chloride (4.6 g, 0.033 mol) was added dropwise with shaking to yield 0.52 g (20%) of **6**, mp 200–202°. Recrystallization from ethanol gave long needles: mp 202–204° (lit. mp 204°,[57] 202–204°[40]); nmr (DMSO-d_6) δ 8.72 s, 8.60 s (2, NH), 7.9–8.2 m (4, *m*-C_6H_5), 7.2–7.7 m (6, *o,p*-C_6H_5), 6.35 q, 6.23 q (1, CH), 1.67 (d, 3, CH_3). The nmr spectrum in DMSO-d_6 suggests the presence of two conformers (1:1 ratio) which exist owing to restricted rotation about the amide C–N bonds.

Anal. Calcd for $C_{16}H_{16}N_2O_2$: C, 71.62; H, 6.01; N, 10.44; mol wt, 268.3. Found: C, 71.42; H, 6.05; N, 10.28; mol wt, 279 (osmometry, chloroform).

***N,N'*-Bis(phenylcarbamoyl)-1,1-diaminoethane (7).**—To anhydrous 2,4,6-trimethyl-1,3,5-hexahydrotriazine (**2a**) (1.29 g, 0.01 mol) in 10 ml of tetrahydrofuran was added phenyl isocyanate (3.6 g, 0.01 mol) and the mixture was allowed to stand at ambient temperature for 24 hr. Removal of solvent, followed by crystallization from benzene, gave 0.25 g (8%) of **7**, mp 215–217°. Recrystallization from ethanol gave needles: mp 225° (lit.[42] mp 220°); nmr (DMSO-d_6) δ 8.50 s (2, NH), 6.4–7.6 m (12, C_6H_5 and NH), 5.33 q (1, CH), 1.42 d (3, CH_3).

Anal. Calcd for $C_{16}H_{18}N_4O_2$: C, 64.41; H, 6.08; N, 18.78; mol wt, 298.34. Found: C, 64.06; H, 6.19; N, 18.06; mol wt, 301 (osmometry, DMF).

Registry No.—**1a**, 75-39-8; **1b**, 40898-94-0; **1c**, 40898-95-1; **1d**, 40898-96-2; **1e**, 40898-97-3; **1f**, 40898-98-4; **1g**, 40898-99-5; **1h**, 40899-00-1; **1i**, 40899-01-2; **2a**, 638-14-2; **2b**, 102-26-1; **2c**, 40899-04-5; **2d**, 40899-05-6; **2e**, 40899-06-7; **2f**, 40899-07-8; **2g**, 40899-08-9; **2h**, 40899-09-0; **6**, 40899-10-3; **7**, 40899-11-4; **10a**, 623-75-6; **10b**, 40899-13-6; **10c**, 28916-22-5; *cis,trans*-**10d**, 40899-15-8; *trans,trans*-**10d**, 40899-16-9; **10e**, 40899-17-0; propanal, 123-38-6; acetaldehyde, 75-07-0; isovaleraldehyde, 590-86-3; butanal, 123-72-8; isobutyraldehyde, 78-84-2; 2-ethylbutanal, 97-96-1; pivaldehyde, 630-19-3; benzoyl chloride, 98-88-4; phenyl isocyanate, 103-71-9.

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