the spectral data. We are grateful to Dr. J. D. Albright for helpful discussion on Me_2SO oxidation.

Registry No. 1, 7044-91-9; 2, 84-65-1; 3, 71774-87-3; 4, 71774-88-4; 5, 71774-89-5.

Lithium–Methylamine Studies. 3. Reduction of Carboxamides

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Benkeser et al.[1] have reduced a number of aliphatic carboxamides to alcohols or aldehydes electrolytically with lithium chloride in methylamine. In those cases in which aldehyde was the primary product, ethanol, an effective proton donor in this system, had been added to the solution. In the electrolytic procedure of Benkeser, *N*-methylalkanamides and *N,N*-dimethylalkanamides produced aldehydes in about 50% yield, while unsubstituted carboxamides were reduced in 25% or lower yield.

Since lithium–amine reduction may differ from electrolytic reduction, we herein report reduction of carboxamides by lithium–methylamine and compare the results with those of amide reduction by the electrolytic–methylamine method of Benkeser.

Results and Discussion

Carboxamides of varying molecular weight and nitrogen substituents were investigated. Reduction of about 0.1 mol of pentanamide, octanamide, *N*-methylpentanamide, *N*-methylhexanamide, and *N*-methyloctanamide with either 2 or 3 equiv of lithium produced only trace amounts of aldehyde. The results of reductions of some other amides with lithium in methylamine are shown in Table I. The unexpectedly small amount of aldehyde formed in the case of *N,N*-dicyclohexylpentanamide is attributed to condensation of the reduction product during the isolation procedure. The percentage of reduced product observed when the amide is added to lithium in solution is less than when lithium is added to the amide in solution. For example, *N,N*-dimethyloctanamide added to a lithium solution produces 27.3% octanal in contrast to the 51.7% octanal produced when lithium is added to dissolved *N,N*-dimethyloctanamide. When lithium is added to dissolved amide, amide reaction (with lithium already in solution) as well as lithium dissolution are occurring during most of the reaction period. The resultant concentration of dissolved, unreacted lithium at any time is considerably lower than 0.23 M (when all added lithium is dissolved but unreacted); hence, the relative concentrations of various reducing species[2] are dependent on the order of addition of reactants.

After treatment of *N,N*-dimethyldecanamide and *N,N*-diethyldecanamide with lithium–methylamine (nonacidic isolation procedure) the product obtained was subjected to a second lithium–methylamine reduction. The yields from these consecutive reductions were 75.3% *N*-methyldecylamine and 20.0% *N*-methyldecanamide from *N,N*-dimethyldecanamide and 76.4% *N*-methyldecylamine with 14.4% *N*-methyldecanamide from *N,N*-diethyldecanamide. Any *N*-methylalkanamide observed must arise from transamidation between starting amide and methylamide ion. Since *N*-methylalkanamides were shown to be relatively resistant to reduction, the percentage of *N*-methylalkanamide formed (15–20%) should be a rough approximation of the extent of the side reaction which forms the *N*-methylalkanamide. This is supported by the 15 and 30% *N*-methylalkanamide isolated in two separate instances as indicated in Table I.

When the product isolation procedure involves basic conditions, imine is obtained; but if the aqueous solution becomes acidic during the extraction process, aldehyde is obtained. No *N*-methylalkylamine is observed among the reaction products, thus indicating that imine was not present during the reduction since it has been shown that imine is readily reduced to amine by lithium in methylamine.[3] The absence of significant quantities of alcohol (formed rapidly from aldehyde in this system[1,3]) in the reaction products leads to the conclusion that little aldehyde is present in the reaction. Since neither aldehyde nor imine appear to be present in the reduction, we have concluded that a carbinolamine anion is a stable intermediate.

When 4 equiv of absolute ethanol was added to *N*-methyloctanamide in methylamine prior to addition of 8 equiv of lithium, a mixture containing 1-octanol and octanal in about a 3:1 ratio was observed. *N,N*-Dimethyloctanamide, when subjected to the same reaction conditions, yielded a slightly higher percentage of alcohol; however, 14.3% *N*-methyloctylamine was obtained from the reduction with no aldehyde being observed. This is

Table I. Reduction of Amides with Lithium in Methylamine

amide	reduction medium[a]	amt Li, equiv	yield of aldehyde, %[b]
$CH_3(CH_2)_3CONHCH_3$	0.423 (6)	2	4.39
$CH_3(CH_2)_6CONHCH_3$	0.113 (10)[c]	6	13.2[f]
$CH_3(CH_2)_3CON(CH_3)_2$	0.139 (8)	2	45.0
$CH_3(CH_2)_4CON(CH_3)_2$[h]	0.0907 (8)[c]	2	48.4
$CH_3(CH_2)_6CON(CH_3)_2$[h]	0.116 (10)[c]	2	51.7
$CH_3(CH_2)_8CON(CH_3)_2$[h]	0.0998 (6)	2	57.9[g]
$CH_2(CH_2)_8CON(CH_2CH_3)_2$[h]	0.0826 (6)	2	54.3[g]
$CH_3(CH_2)_3CON(C_6H_{11})_2$[h]	0.0848 (0.23)	2	trace[d,e]

[a] In all of these reactions 500 mL of methylamine was used, the first value is moles of amide and the reaction time, in hours, is in parentheses. [b] The products reported were identified by IR and NMR spectra. [c] The solution was blue, indicating imcomplete reaction of all added lithium when the reaction was quenched. [d] The product gave a positive (2,4-dinitrophenyl)hydrazine test. [e] See the Experimental Section for details of this reduction. [f] Isolated as *N*-octylidenemethylamine. [g] *N*-Methyldecanamide was also isolated (29.2% from *N,N*-dimethyldecanamide and 13.7% from *N,N*-diethyldecanamide). [h] Certain physical constants (d, n_D, MR_D) of this compound are reported in *J. Chem. Eng. Data*, 21, 247 (1976).

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the only instance in numerous lithium–amine reductions of carboxylic acids[2] or amides in which an amine product was observed in spite of the fact that efforts were made to do so and is attributed to solution pH change with alcohol present as well as to the absence of hydrogen on the amide nitrogen.

The most dramatic differences between reduction in the lithium–methylamine system and electrolytic reductions in methylamine are the appearances in the former reduction of (1) transamidation product and (2) RCH_2NHCH_3 when added ethanol is present. The yields of aldehyde from tertiary amide are comparable in lithium–methylamine and electrolytic reductions in methylamine–ethanol. The electrolytic reductions of secondary and tertiary amides yield roughly comparable amounts of product, whereas, in the nonelectrolytic reductions herein reported, primary and secondary amides afford poor yields of reduction product, but the tertiary amides give appreciably more product. It appears that in electrolytic reduction, most of the reaction is taking place at the electrode, and the absence of any significant amount of methylamide ion in that system prevents occurrence of transamidation. The electrolytic method gives better reduction of primary and secondary amides. However, lithium–methylamine reduction would appear to be the method of choice for reduction of tertiary amides, since the equipment needed is relatively common, and the yield of aldehyde is slightly higher. In addition to these advantages no reduction to alcohol is observed, whereas reduction to alcohol quite often occurs in the electrolytic process. The one disadvantage in the reduction of tertiary amides by lithium–methylamine is that 15–20% transamidation may occur.

Experimental Section

Melting and boiling points are reported uncorrected. Elemental analysis was performed by Galbraith Laboratories, Inc., Knoxville, TN. Low sodium content lithium ($^1/_8$ in. wire) from Lithcoa and anhydrous methylamine from Matheson were used in the reductions. Chemicals used in this study which were purchased were *N,N*-dimethylpentanamide, *N,N*-diethyldecanamide, dimethylamine (Eastman), pentanamide (Baker), *N,N*-dicyclohexylamine (Abbott Laboratories), pentanoic acid, hexanoic acid, octanoic acid (Aldrich), and a Hallcomid mixture (C. P. Hall). This latter mixture after two vacuum fractional distillations produced *N,N*-dimethyloctanamide [bp 60° C (0.01 torr); lit.[4] bp 187 °C (100 torr)] and *N,N*-dimethyldecanamide [bp 80–81 °C (0.01 torr)].

Preparation of Amides. The procedure of Philbrook[5] was modified in that ether was substituted for benzene as the reaction solvent in preparing octanamide, *N*-methylpentanamide, *N*-methylhexanamide, and *N*-methyloctanamide. *N,N*-Dimethylhexanamide was prepared in a manner similar to that described by Bryden and Pauling.[6] Analysis of *N,N*-dicyclohexylpentanamide prepared by the Schotten–Baumann method[7] was as follows. Anal. Calcd: C, 76.92; H, 11.77; N, 5.28. Found: C, 77.06; H, 11.98; N, 5.28.

General Procedure. In a three-necked Pyrex flask fitted with a mechanical stirrer, gas-inlet tube, and dry ice condenser with mercury trap attached was placed the amide to be reduced. After the system was purged (dry N_2), methylamine was condensed in the flask, stirring was commenced and 2 equiv of lithium was added. After 6–8 h or loss of the blue color, the mixture was decomposed with 200 mL of saturated aqueous NH_4Cl. The dry ice condenser was removed after half the NH_4Cl had been added. Water (100 mL) was added to facilitate solution and extraction. After the mixture was extracted five times with 100-mL portions of ether, the combined extracts were washed with 20-mL portions of 10% HCl until the washings were acidic to litmus, followed by washing with 20 mL of dilute aqueous Na_2CO_3 and finally with two 50-mL portions of distilled water. The ether solution was dried (Na_2SO_4), the ether stripped off under aspirator vacuum, and the product isolated by vacuum distillation where practicable. Products were identified by comparison of IR and NMR spectra with those of authentic samples where possible. The conditions of these reductions can be ascertained from Table I.

Reduction of *N,N*-Dimethyloctanamide by Inverse Addition. *N,N*-Dimethyloctanamide (9.80 g, 0.0572 mol) dissolved in 30 mL of ether and placed in a pressure-equalizing dropping funnel was added to a solution (dark blue) of lithium (0.807 g, 0.116 g-atom) dissolved in 300 mL of methylamine. Addition of the amide required about 10 min, although the solution became colorless before addition was complete. By use of the isolation procedure described above, 2.00 g (27.3%) of octanal [bp 41.8° (2.25 torr)] was obtained.

Reduction of *N,N*-Dicyclohexylpentanamide with 2 Equiv of Lithium in Methylamine. Following the general procedure described above, we added 1.19 g (0.171 g-atom) of lithium to 22.5 g (0.0848 mol) of *N,N*-dicyclohexylpentanamide in 300 mL of methylamine. Within 1 min blue streaks appeared and vanished almost as rapidly as they appeared. The reaction mixture turned blue 4 min after addition of lithium began and was colorless 13 min after addition of lithium began. After the mixture was decomposed with 200 mL of saturated aqueous NH_4Cl and the ether extracted, acidification of the combined extracts produced a pastelike precipitate which was isolated by suction filtration and identified as dicyclohexylamine hydrochloride by comparison with an authentic sample. Only a trace of pentanal (identified by a positive (2,4-dinitrophenyl)hydrazine test) was recovered from the filtrate.

Reduction of *N*-Methyloctanamide with 4 Equiv of Absolute Ethanol and 8 Equiv of Lithium in Methylamine. The general procedure described above was modified by adding 4 equiv of absolute ethanol to the amide in the reaction flask prior to condensation of methylamine. When 29.3 g (0.186 mol) of *N*-methyloctanamide, 36.6 g (0.794 mol) of absolute ethanol, and 10.4 g (1.49 g-atom) of lithium were allowed to react in 500 mL of methylamine, the solution became colorless within 8 h. The general isolation procedure already described produced 2.10 g of octanal [8.61%; bp 34 °C (0.04 torr)] and 7.00 g of 1-octanol [28.3%; bp 47 °C (0.07 torr)].

Reduction of *N,N*-Dimethyloctanamide with 8 Equiv of Lithium in Methylamine in the Presence of 4 Equiv of Ethanol. *N,N*-Dimethyloctanamide (16.7 g, 0.0975 mol), absolute ethanol (18.4 g, 0.399 mol), and 500 mL of methylamine were allowed to react with lithium (5.55 g, 0.800 g-atom) in the manner described for *N*-methyloctanamide, vide supra. After 9 h the solution was decomposed, extracted, and acidified. This extract afforded 1-octanol (5.10 g, 40.2%). After addition of K_2CO_3 to make the aqueous solution alkaline, two 40-mL extractions with ether allowed isolation of 2.00 g of *N*-methyloctylamine [14.3%; bp 51 °C (1.65 torr)].

Reduction of *N,N*-Dimethyldecanamide to *N*-Methyldecylamine. *N,N*-Dimethyldecanamide (30.0 g, 0.151 mol) and lithium (2.10 g, 0.302 g-atom) in 500 mL of methylamine were allowed to react for 10 h. After dropwise addition of 200 mL of saturated aqueous NH_4Cl, five 100-mL extractions with ether, combination of the ethereal extracts, and removal of ether by distillation, the *N*-decylidenemethylamine isolated was allowed to react 8 h with 2.10 g (0.302 g-atom) of lithium and 400 mL of methylamine in the apparatus previously described for lithium–methylamine reductions. After hydrolysis (200 mL of water), extraction (five 100-mL portions of ether), drying of combined extracts (Na_2SO_4), and stripping off of the ether, vacuum distillation produced 17.2 g (66.4%) of *N*-methyldecylamine, bp 41–43 °C (0.15 torr). From the distillation residue, 5.60 g (20.0%) of *N*-methyldecanamide was isolated by recrystallizaton from ethanol–water.

Reduction of *N,N*-Diethyldecanamide to *N*-Methyldecylamine. *N,N*-Diethyldecanamide (33.1 g, 0.146 mol) and lithium (2.12 g, 0.305 g-atom) in 500 mL of methylamine were allowed

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to react for 12 h. After dropwise addition of 200 mL of saturated aqueous NH_4Cl, five 100-mL extractions with ether were carried out, the ethereal extracts were combined, and the ether was distilled off. The resultant imine was subjected to a 5-h reduction by 2.08 g (0.300 g-atom) of lithium in 500 mL of methylamine. The solution was hydrolyzed (200 mL of water) and extracted (five 100-mL portions of ether), and the combined extracts were dried (Na_2SO_4). After the ether was stripped off, the product was distilled at atmospheric pressure to give 19.1 g (76.4%) of *N*-methyldecylamine [bp 216–218 °C (lit.[3] bp 224 °C)]. *N*-Methyldecanamide (3.90 g, 14.4%) was obtained from the distillation residue.

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Registry No. *N*-Methylpentanamide, 6225-10-1; *N*-methyloctanamide, 1119-57-9; *N*,*N*-dimethylpentanamide, 6225-06-5; *N*,*N*-dimethylhexanamide, 5830-30-8; *N*,*N*-dimethyloctanamide, 1118-92-9; *N*,*N*-dimethyldecanamide, 14433-76-2; *N*,*N*-diethyldecanamide, 2602-61-1; *N*,*N*-dicyclohexylpentanamide, 59048-92-9; pentanal, 110-62-3; *N*-octylidenemethylamine, 53106-86-8; hexanal, 66-25-1; decanal, 112-31-2; *N*-methyldecanamide, 23220-25-9; 1-octanol, 29063-28-3; *N*-methyloctylamine, 2439-54-5; *N*-methyldecylamine, 7516-82-7; dicyclohexylamine hydrochloride, 4693-92-9; octanal, 124-13-0.

Reactions of Some Aromatic Nitro Compounds with Alkali Metal Amides

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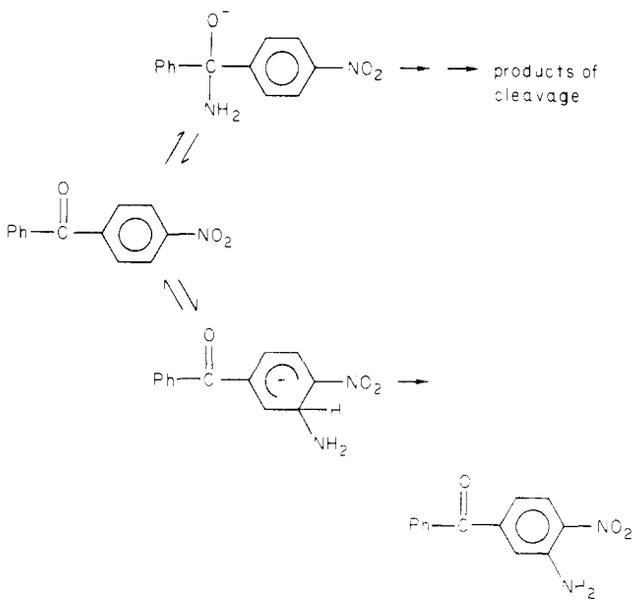
During recent studies on cleavage of substituted benzophenones by potassamide in ammonia,[1] we noted an interesting competing reaction in the case of 4-nitrobenzophenone. This has prompted further examination of this and similar reactions of a number of other aromatic nitro compounds.

4-Nitrobenzophenone would be expected to undergo reversible addition of amide ion at the carbonyl group and eventually to yield benzoic acid and nitrobenzene if cleavage followed.[2] Benzoic acid was in fact isolated from a somewhat sluggish reaction of 4-nitrobenzophenone and potassamide in ammonia from which 45% of the ketone was recovered, but no nitrobenzene was detected. This became understandable when it was noted that nitrobenzene was readily consumed under the reaction conditions to give a complex mixture of products. Competing with the cleavage was an unexpected reaction leading to a product $C_{13}H_{10}N_2O_3$ which contained amino, carbonyl, and nitro groups (^1H NMR and IR spectra). Examination of the mass spectrum permitted elaboration of the formula to $C_6H_5COC_6H_3(NH_2)(NO_2)$ from the breakdown pattern $M^+ \rightarrow C_6H_5CO$ (*m/e* 105). The choice between 2-amino- and 3-amino-4-nitrobenzophenone was determined in favor of the 3-substituted compound from the breakdown pattern $M^+ \rightarrow C_6H_5COC_6H_3(NH)(NO)$ (*m/e* 225), the result of loss of OH between the amino and nitro groups via a cyclic transition state (ortho effect).[3] The matter was clinched by comparison with an authentic sample of the 2-amino compound[4] which showed a different mass spectral breakdown (specifically, no peak at *m/e* 225), a different IR spectrum, different chromatographic (TLC) characteristics, and a melting point depression on admixture with the compound obtained from 4-nitrobenzophenone. Similar considerations (^1H NMR and mass spectra) allow the likely identification of a byproduct in the reaction as 3-hydroxy-4-nitrobenzophenone, although this compound was not isolated in a pure condition [breakdown patterns: $M^+ \rightarrow C_6H_5CO$ (*m/e* 105), $M^+ \rightarrow C_6H_5COC_6H_3(O)(NO)$ (*m/e* 226), no peak observed at *m/e* 165 as would be expected[5] for the 2-hydroxy isomer].

Scheme I



The two observed reaction courses become intelligible if we assume that two different equilibria are established between 4-nitrobenzophenone and amide ion, one of which leads ultimately to cleavage and the other, by loss of hydride ion, to amination (see Scheme I). Such amination reactions find precedent in the behavior of various aromatic nitro compounds with alkali metal piperidides and diphenylamides[6] and with the hydroxylation of nitrobenzene by potassium hydroxide,[7] although substrate reduction is a complication in some of these reactions.

We next examined the behavior of 4-nitrodiphenyl sulfone and of 4-nitrodiphenyl sulfoxide. When 4-nitrodiphenyl sulfone in ethanol was treated with potassamide in ammonia, competitive substitution reactions occurred, leading to 4-ethoxydiphenyl sulfone and 4-ethoxynitrobenzene, with the former predominating; however, the corresponding amino compounds were produced when tetrahydrofuran was used as cosolvent. 4-Nitrodiphenyl

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