

The products from A, B, C, and D were identical in complete elemental analyses, mixture melting points, infrared and nuclear magnetic resonance spectra.

3-Butyl-4-methyl-1-isopropyl-2-imidazolone (IIIb).—A solution of 3-butyl-1-isopropyl-1-(2-propynyl)urea (19.6 g., 0.1 mole) and phosphorus pentachloride (20.8 g., 0.1 mole) in 150 ml. of benzene was gradually heated and held at reflux for 4 hr. until hydrogen chloride was no longer evolved. On cooling, a brown oil separated. The oil was taken up in 100 ml. of water, and made alkaline with 20% sodium hydroxide. The product separated as an oil. Distillation gave a colorless oil, b.p. 115–119° (2.0 mm.), n_D^{25} 1.4780, 14.2 g., 72.7% yield.

Anal. Calcd. for $C_{11}H_{20}N_2O$: C, 67.45; H, 10.20; N, 14.30. Found: C, 67.15; H, 10.02; N, 14.24.

Direct Reduction of Carboxylic Acids to Aldehydes by Lithium in Ethylamine¹

ALBERT W. BURGSTAHLER, LEONARD R. WORDEN, AND
TOM B. LEWIS

Department of Chemistry, University of Kansas, Lawrence, Kansas

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The synthesis of an aldehyde from a carboxylic acid ordinarily involves transformation of the acid into a derivative which subsequently is reduced.² In recent work in this laboratory we observed the direct reduction of a carboxylic acid to an aldehyde when dehydroabiatic acid was treated with lithium in ethylamine over a prolonged period in the absence of an added proton source.³ This interesting result, all the more remarkable because an excess of reducing agent was present throughout the reaction, prompted an investigation of the action of lithium in ethylamine on a number of other carboxylic acids.

In the present study we found that primary and secondary carboxylic acids, as well as tertiary carboxylic acids such as dehydroabiatic acid, are reduced to aldehydes by lithium in ethylamine. Although yields as high as 80% were observed, generally they were much lower (see Table I). Efforts to find optimum conditions for the reduction by variation of the temperature, time, and method of quenching were of only limited success. Best results were obtained at the boiling point of anhydrous ethylamine (17°), which was satisfactory for use without a cosolvent except in the case of stearic acid, which was reduced in considerably higher yield in the presence of an equal volume of ether. Generally a reaction time of four to six hours proved to be most effective. Quenching the reaction with ammonium chloride gave higher yields than quenching with water, alcohol, or ammonium acetate.

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TABLE I
LITHIUM-ETHYLAMINE REDUCTION OF CARBOXYLIC ACIDS

Acid	Temp., °C.	% yield aldehyde ^a	% re-covered acid ^b
Trimethylacetic acid	−78	0	0
	0	14	0
Cyclohexanecarboxylic acid	−78	0	0
	0	27	0
	17	20	20
	17°	18	0
1-Methyleyclohexanecarboxylic acid	17	26	60
Octanoic acid	17	26	5
Undecanoic acid	17	30	5
Lauric acid	0	21	3
	17	64	8
Stearic acid	17	40	0
	17°	72	0
Dehydroabiatic acid	17	80 ^d	0
Podocarpic acid methyl ether	17	0 ^d	100

^a Yields of aldehyde were determined by isolation of the 2,4-dinitrophenylhydrazones, whose melting points were compared with standard values (cf. ref. 11). ^b See Experimental. ^c Ether was employed as a cosolvent. ^d The aromatic ring also was reduced (cf. ref. 3).

Although the yields of aldehyde generally were better from acids of higher molecular weight than from those of lower molecular weight, the reaction does not appear to be affected appreciably by steric factors, since the yields of aldehyde from lauric acid and dehydroabiatic acid³ (primary and tertiary acids, respectively) were approximately equal. On the other hand, the highly hindered axial carboxyl group in podocarpic acid methyl ether was not reduced.

With respect to the mechanism of the reduction, the action of lithium in ethylamine on the preformed lithium salt of lauric acid gave only an 11% yield of aldehyde as opposed to a 64% yield obtained when lithium was added to a solution of the free acid in ethylamine. This suggests that these reductions occur preferentially *via* the ethylamine salt of the acid. Moreover, since isolation of the aldehyde did not require treatment of the reaction mixture with strong acid, it appears likely that a simple hydride addition product rather than a dihydroamidine^{2e} or similar base-stable intermediate is formed during the reduction. In any event, the reduction was shown *not* to occur *via* dehydrogenation of an intermediate alcohol, as in the work of Smith and co-workers,⁴ since 1-octanol was unaffected when treated with lithium in ethylamine under conditions which led to the reduction of octanoic acid. In contrast to the nonreducing nature of the medium employed by Smith, *et al.*, our system contains reducing species (blue solution of lithium in ethylamine) throughout the entire reaction period.

Since only fair yields of aldehydes were obtained in most of these reductions, a more extensive investigation of applications of this procedure has not been undertaken. Furthermore, since aromatic,⁵ olefinic,⁶ and other centers of unsaturation^{6,7} also are reduced by

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lithium in ethylamine, the reaction is obviously limited to saturated carboxylic acids unless reduction of other functional groups is intended. Additional efforts to increase the yield of aldehyde by the use of other solvents such as ethylenediamine were relatively unsuccessful unless a considerable amount of ethylamine also was present.

Experimental

The general procedure for the reduction of acids to aldehydes with lithium in ethylamine is illustrated by the reduction of undecanoic acid.

Finely divided lithium shot⁸ (0.75 g., 0.11 g.-atom) was added to a magnetically stirred solution of undecanoic acid (1.86 g., 0.01 mole) in anhydrous, redistilled ethylamine (35 g., 50 ml.) in a 100-ml. three-necked flask fitted with a soda-lime drying tube, a dewar-type reflux condenser,⁹ and a flexible-necked addition flask¹⁰ containing (40 g., 0.9 mole) of anhydrous ammonium chloride. After 4 hr. the deep blue color of the mixture was discharged by careful addition of the ammonium chloride. The condenser then was removed, and after partial evaporation of the solvent for 1 hr. at room temperature the residue was added to a mixture of 65 g. of cracked ice and 35 ml. of concentrated hydrochloric acid. The resulting acidic solution was extracted with 100 ml. of ether, and the ether layer was washed with cold 1 N sodium hydroxide solution to yield 90 mg. (5% recovery) of unchanged undecanoic acid. The ether layer then was dried and evaporated to give a mixture of undecanol and undecanal from which the aldehyde was isolated and identified as its 2,4-dinitrophenylhydrazone (1.05 g., 30% yield), m.p. 102.5–103.5°. For further identification the aldehyde from another run was converted into the semicarbazone, m.p. 104–106°.¹¹

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The Structures of Methazonic Acid and Its Anions¹

S. BROWNSTEIN

Division of Applied Chemistry, National Research Council,
Ottawa, Canada

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The reaction of nitromethane with base first yields the nitromethane anion, then the methazonate ion.² The rates of these reactions have been determined and some suggestions made about mechanism.^{3–5} However, the structures of methazonic acid and its anion have not been definitely established. Since proton resonance spectroscopy has been very useful in determining structures of mobile species in solution, an

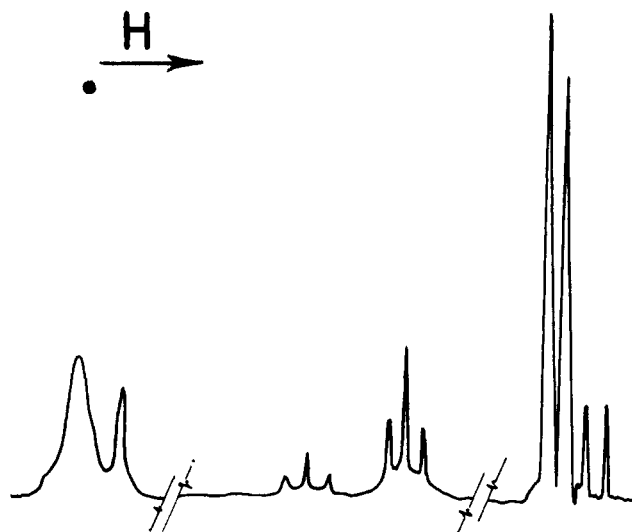


Fig. 1.—Proton resonance spectrum of methazonic acid in acetone (solvent not shown).

attempt was made to obtain the spectra of methazonic acid and its anion.

The proton resonance spectrum of methazonic acid in acetone solution is shown in Fig. 1. A similar spectrum is observed in aqueous solution except for the absence of the two low field peaks, attributed to the oxime protons, which are presumably exchanging rapidly with the solvent. Chemical shifts and spin-coupling constants are listed in Table I. The doublet, triplet, and single peaks observed for methazonic acid may be most readily explained if the compound has the structure $O_2NCH_2CH:NOH$. The two groups of peaks can be attributed to *syn-anti* isomerism about the carbon–nitrogen bond. The aldehydic proton in aldoximes has been found to occur at lowest magnetic field in the *syn* isomer.⁶ Although no effect of *syn-anti* isomerism was observed on the β -hydrogens in aldoximes it has been observed in 2,4-dinitrophenylhydrazones and ketoximes.^{7,8} It is, therefore, concluded that the lowest field triplet, highest field doublet, and highest field singlet can be assigned to the *syn* isomer of methazonic acid. As with the 2,4-dinitrophenylhydrazones the shielding effect of the carbon–nitrogen double bond is opposite for the α - and β -hydrogens, and smaller for the β - than the α -hydrogens.

An AX_2 spectrum for the protons on the carbon chain in both isomers of methazonic acid indicates either free rotation about the carbon–carbon bond or a fixed conformation in which the two CH_2 protons are equivalent. Since the average coupling constants are different for the two isomers, it is likely that there is free rotation about the carbon–carbon bond, with different populations in the various conformations for each isomer.

The spectrum of a freshly prepared acetone solution of methazonic acid shows only those peaks attributed to the *anti* form. With time, peaks due to the *syn* isomer appear, and at equilibrium it is the more abundant by 1.29:1.00. When methazonic acid is dissolved in water the equilibrium concentrations of *syn*

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