paper chromatography of R_f(B) 0.32, R_f(C) 0.39, R_f(D) 0.43. The optical rotatory dispersion curve of compound I (Figure 1) has a large peak at 275 mμ and a trough at 220 mμ, giving a Cotton curve around 260 mμ (positive). This suggests that I has the cyclonucleoside structure in conformity with previous observations[13] of other cyclonucleosides of purine. Moreover, an abnormally large amplitude (47,200°) suggests that the base is in the *anti* position. These data together with the following cleavage reaction showed the structure of the compound I to be correct.

When the acidic hydrolysis of III was carried out in 0.1 *N* sulfuric acid for 10 hr, a new compound (V) was obtained together with compound IV and 8-oxyadenine (VI). Compound V, mp 170° dec, obtained by recrystallization from 50% ethanol, showed ultraviolet absorption ($\lambda_{max}^{0.1N\,HCl}$ 260 (shoulder), 273 mμ, $\lambda_{max}^{H_2O}$ 250 (shoulder), 266.5 mμ, $\lambda_{max}^{0.1N\,NaOH}$ 273 mμ) which closely resembled that of 8-methoxyadenine[14] and infrared absorption (λ_{max}^{KBr} 1740 cm^{-1} (aldehyde)). R_f values were R_f(B) 0.08, R_f(C) 0.28, and R_f(D) 0.13. These properties together with elemental analyses indicate that compound V has the structure 5-(adenyl-8-)-D-ribose. These hydrolysis experiments prove the anhydro linkage in compound I and III to be in 8,5′ position.

The new method for the cyclization of purine nucleosides could be applied to nucleosides having a sugar moiety in which the secondary hydroxyl group is in the "up" configuration. The method also will be applicable to pyrimidine nucleosides having halogeno substituents in the appropriate positions. Experiments along these lines are in progress.

[13] M. Ikehara, M. Kaneko, K. Muneyama, and H. Tanaka, *Tetrahedron Letters*, 3977 (1967).

[14] R. K. Robins, *J. Am. Chem. Soc.*, **80**, 6671 (1958).

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Exchange Reactions of Carboxylic Acid Salts. A Facile Preparation of α-Deuteriocarboxylic Acids[1]

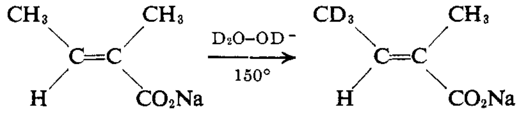
Sir:

The early literature of deuterium chemistry contains a number of papers on the exchange behavior of carboxylic acids.[2,3] These were largely kinetic studies which were followed by combustion analysis, and did not permit the unambiguous location of exchange in the compounds. Recently, there has been renewed interest in the lability of the α protons of carboxylic acids,[4–6] and we wish to report the results of a detailed reinvestigation of the early exchange reactions with D_2O.[7]

We have found that simply refluxing a concentrated solution of sodium or potassium acetate in basic deuterium oxide causes ready exchange of the protons of the methyl group with a half-life of 3–5 hr (eq 1). The reaction is quite general and one immediate consequence of this discovery is that it provides a simple, one-step preparation of a wide variety of α-deuteriocarboxylic acids. However, aliphatic substitution on the α carbon of acetic acid slows the exchange rate severalfold so that, although it is possible to exchange higher acids at reflux, the rather long reaction times are best avoided by running the exchange in a stainless-steel bomb at 150°. The general procedure involved dissolving 0.5 mole of the sodium or potassium salt in 200 ml of D_2O containing 0.05 mole of OD^-, heating at 150° for 24 hr, removing the spent D_2O, and adding fresh heavy water. Five such exchanges usually sufficed to bring the isotopic content to >98 atom % D. The free acids were recovered by acidification of the aqueous solutions and could be purified by distillation or recrystallization without loss of deuterium.

The extent and location of deuteration were determined by nmr. In no case of those reported here was there evidence for exchange at any but the α (or vinylogously α) carbon atom. A careful check was made on propionic-α,α-d_2 acid which was converted to the ethyl ester and analyzed by mass spectrometry. A maximum of 0.5% d_3 species was present, indicating that a homoenolic mechanism is not operating.[8,9] Table I contains a list of the deuterated acids prepared in this work.

$$CH_3CO_2Na \xrightarrow[120°]{D_2O-OD^-} CD_3CO_2Na \qquad (1)$$



(2)

Runs 1–11 in Table I represent the aliphatic monocarboxylic acids exchanged as their potassium salts. The deuteration in all cases was excellent with the exception of cyclopropanecarboxylic acid.[6] A series of aliphatic dicarboxylic acids from C_4 to C_8 was exchanged, with the results shown in Table I, runs 12–16. It can be seen that α,α,α′,α′-tetradeuteriodicarboxylic acids can be thus readily prepared with high isotopic purity and good chemical yield. Runs 17–20 in Table I show the results of exchange of several arylacetic acids. As might be expected, exchange proceeds quite readily, the half-life of exchange of sodium phenylacetate being 8 min at 85°.[10]

Several α,β-unsaturated carboxylic acids and toluic acids were then investigated to determine whether the activating influence of the carboxylate group would be extended by conjugation. This was found to be the case as shown for tiglic (eq 2) and senecioic acids (runs

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[1] Synthetic Aspects of Stable Isotope Chemistry. IV. For previous papers in this series, see: (a) J. G. Atkinson, D. M. MacDonald, R. S. Stuart, and P. H. Tremaine, *Can. J. Chem.*, **45**, 2583 (1967); (b) J. G. Atkinson, M. O. Luke, and R. S. Stuart, *Chem. Commun.*, 474 (1967); *Can. J. Chem.*, **45**, 1511 (1967); (c) J. G. Atkinson, M. H. Fisher, D. Horley, A. T. Morse, R. S. Stuart, and E. Synnes, *ibid.*, **43**, 1614 (1965).

[2] D. J. G. Ives and R. H. Kerlogue, *J. Chem. Soc.*, 1362 (1940), and earlier papers cited therein.

[3] L. D. C. Bok and K. H. Geib, *Z. Physik. Chem.*, **A183**, 353 (1939).

[4] Y. Kawazoe and M. Ohnishi, *Chem. Pharm. Bull.* (Tokyo), **14**, 1413 (1966).

[5] P. L. Creger, *J. Am. Chem. Soc.*, **89**, 2500 (1967).

[6] A. T. Bottini and A. J. Davidson, *J. Org. Chem.*, **30**, 3302 (1965).

[7] Presented in part at the Second International Conference on Methods of Preparing and Storing Labelled Molecules, Brussels, Belgium, Nov 28–Dec 3, 1966.

[8] A. Nickon, J. L. Lambert, R. O. Williams, and N. H. Werstiuk, *J. Am. Chem. Soc.*, **88**, 3354 (1966).

[9] A further check on this possibility is being carried out on trimethylacetic acid.

[10] Detailed studies of the kinetics of exchange of a series of ring-substituted phenylacetic acid salts are being carried out by Dr. P. Bélanger in these laboratories and will be reported shortly.

Table I. α-Deuteriocarboxylic Acids Prepared by Exchange

Run	Acid	Structure	Atom % D[a]	Yield, %[b]
1	Acetic	CD_3CO_2K	99.6	76[c]
2	Propionic	$CH_3CD_2CO_2H$	99.5	44
3	*n*-Butyric	$CH_3CH_2CD_2CO_2H$	99.5	30
4	Isobutyric	$(CH_3)_2CDCO_2H$	99.5	34
5	Cyclopropanecarboxylic	$(CH_2)_2CDCO_2H$	<10	25
6	Cyclobutanecarboxylic	$(CH_2)_3CDCO_2H$	97	40
7	Cyclopentanecarboxylic	$(CH_2)_4CDCO_2H$	>94	40
8	Cyclohexanecarboxylic	$(CH_2)_5CDCO_2H$	97.7	38
9	Hydrocinnamic	$C_6H_5CH_2CD_2CO_2H$	98.5	54
10	Phenoxyacetic	$C_6H_5OCD_2CO_2H$	99.5	67
11	5-Phenoxypentanoic	$C_6H_5O(CH_2)_3CD_2CO_2H$	98.9	91
12	Succinic	$(CD_2CO_2H)_2$	99.5	81
13	Glutaric	$CH_2(CD_2CO_2H)_2$	99.5	32
14	Adipic	$(CH_2CD_2CO_2H)_2$	99.5	82
15	Pimelic	$CH_2(CH_2CD_2CO_2H)_2$	99.5	78
16	Suberic	$(CH_2CH_2CD_2CO_2H)_2$	99	64
17	Phenylacetic	$C_6H_5CD_2CO_2H$	99.5	66
18	3,4-Dimethoxyphenylacetic	$3,4\text{-}(CH_3O)_2C_6H_3CD_2CO_2H$	99	55
19	α-Naphthylacetic	$\alpha\text{-}C_8H_7CD_2CO_2H$	99	68
20	Diphenylacetic	$(C_6H_5)_2CDCO_2H$	99.6	60
21	Tiglic	*cis*-$CD_3CH{=}C(CH_3)CO_2H$	99.5	33
22	Angelic	*trans*-$CD_3CH{=}C(CH_3)CO_2H$	99.5	30[d]
23	Senecioic	$(CD_3)_2C{=}CDCO_2H$	99.2	25
24	*o*-Toluic	*o*-$CD_3C_6H_4CO_2H$	96.1	39
25	*p*-Toluic	*p*-$CD_3C_6H_4CO_2H$	98.2	42
26	*m*-Toluic	*m*-$CD_3C_6H_4CO_2H$	94	40
27	*p*-Tolylacetic	*p*-$CD_3C_6H_4CD_2CO_2H$	CD_2 99 CD_3 93	24

[a] Atom per cent D in the indicated position. [b] Yield of recovered, purified acid. [c] Recovered only as the salt. [d] Prepared from tiglic-d^3 acid as by R. E. Buckles and G. V. Mock, *J. Org. Chem.*, **15**, 680 (1950).

21 and 23). It was also found that *o*- and *p*-toluic acids (runs 24 and 25) exchanged the methyl protons, although a temperature of 180° was required for equilibrium to be reached within 48 hr. *m*-Toluic acid (run 26), rather surprisingly, was found to exchange at a rate which was only some three–five times slower than that of the *ortho* and *para* compounds. *p*-Tolylacetic acid (run 27) was then found to exchange the methyl as well as the methylene protons, but toluene did not exchange under the same conditions. It thus appears that the carboxylate group in the toluic acids promotes exchange as much by permitting a homogeneous solution as by direct activation.

From a preparative point of view, the scope of these exchanges allows the preparation of a number of labeled organic compounds—alcohols, amines, halides, etc.—which are easily obtained from carboxylic acids by standard reactions. Although we have worked only with deuterium, the same procedure should also allow the preparation of the corresponding tritiated compounds.

Bottini and Davidson[6] considered that the exchange of their unsaturated cyclopropylcarboxylates proceeded through a dianion intermediate. Although this is a very reasonable mechanism, two others merit consideration. One involves an intramolecular removal of an α proton by the carboxylate anion which then reacts with the solvent. The other possibility involves the attack of base on the small amount of free carboxylic acid present from hydrolysis of the salt.[11] Work is being carried out[10] to try to distinguish among these different possibilities.

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(11) As pointed out by a referee, the data in ref 6 show that these alternative mechanisms are not important in the exchange of the methylenecyclopropanecarboxylic acid salts, and by a reasonable extrapolation may not be operating in the exchanges described in the present work.

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Reaction of Carbon Monoxide at Atmospheric Pressure with Trialkylboranes in the Presence of Lithium Trimethoxyaluminohydride. A Convenient Procedure for the Conversion of Olefins into Aldehydes *via* Hydroboration

Sir:

We have previously reported that the carbonylation of organoboranes[1] produced *via* hydroboration[2] pro-

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