stirred further in nitrogen for 1 hr and then refluxed for 0.5 hr and stirred to cool. After filtration from the reaction mixture, the gray solid (0.7 g, 25%) was washed twice with benzene and then with ether and dried *in vacuo*, mp 210–214° dec.

Anal.—Calc. for $C_{31}H_{23}BrNO_2P$: C, 67.40; H, 4.20; N, 2.54. Found: C, 67.27; H, 4.18; N, 2.64.

9-(3-Nitrofluorenyl)isothiuronium Bromide (Ie)—Compound Ia (2.9 g, 0.01 mole) and thiourea (0.76 g, 0.01 mole) were ground together thoroughly. To the mixture were added 1-butanol (8 ml) and aqueous 48% HBr (1 ml). The mixture was refluxed with occasional shaking for 0.5 hr and cooled. The crystalline product was collected, washed successively with small amounts of 1-butanol, carbon tetrachloride, chloroform, and ether, and air dried, giving 3.45 g (93%), mp 210–215° dec.

Anal.—Calc. for $C_{14}H_{12}BrN_3O_2S$: C, 45.91; H, 3.30; N, 11.47; S, 8.75. Found: C, 45.77; H, 3.22; N, 11.28; S, 8.76.

3-Nitrofluoren-9-p-toluenesulfonylhydrazone (If)—p-Toluenesulfonylhydrazine (11) (15.4 g, 0.083 mole) and 3-nitrofluoren-9-one (15 g, 0.067 mole) were suspended in absolute ethanol (150 ml). The suspension was heated with stirring under reflux for 1.5 hr and cooled. The brown crystalline product was collected, washed with 100 ml of boiling ethanol, and dried, giving 20.5 g (78%), mp 194–197° dec.

The product (0.5 g) was purified by repeated washing with boiling ethanol and recrystallization from chloroform–benzene to give lustrous orange crystals, 0.3 g, mp 205–206° dec.; IR (mineral oil): 3230, 1583, 1515, 1365, 1330, and 1150 cm^{-1}.

Anal.—Calc. for $C_{20}H_{15}N_3O_4S$: C, 61.06; H, 3.84; N, 10.68. Found: C, 60.94; H, 3.93; N, 10.24.

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COMMUNICATIONS

Decarboxylation Kinetics of 5-(Tetradecyloxy)-2-furoic Acid

Keyphrases □ Decomposition—solid-state reactions, decarboxylation kinetics, hypolipidemic agent, 5-(tetradecyloxy)-2-furoic acid □ Kinetics—solid-state activation energy, decarboxylation, decomposition, 5-(tetradecyloxy)-2-furoic acid □ 2-Furoic acid, 5-tetradecyloxy—hypolipidemic agent, solid-state decomposition, kinetics

To the Editor:

Single-component solid reactions are of several types: *e.g.*, a solid can form a solid and a gas (type I) or a liquid and a gas (type II). A type I reaction is exemplified by oxygen formation from permanganates, whereas the formation of liquid aniline and gaseous carbon dioxide from decarboxylation of p-aminobenzoic acid denotes a type II reaction. This paper reports a type II reaction of a pharmaceutical solid, 5-(tetradecyloxy)-2-furoic acid[1], which is a novel hypolipidemic agent (1).

Decarboxylation kinetics in the solid state have been reported (2–7), and several reported reactions (3, 5, 6) were type II. This paper deals with carboxylic acid, RCOOH, where R = $C_{14}H_{29}O-(C_4H_2O)-$ and where $(C_4H_2O)-$ is a furan moiety. The compound decomposes *via* the reaction shown in Scheme I, where RH is liquid in the temperature range studied; hence, the reaction is type II.

$$RCOOH \rightarrow RH + CO_2$$
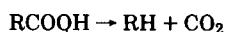
Scheme I

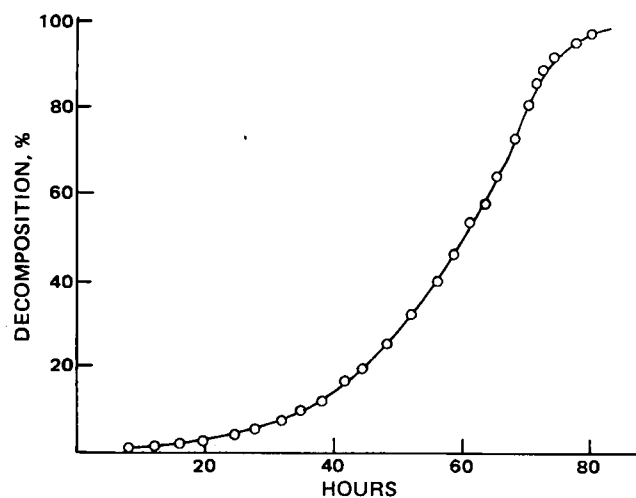An apparatus such as the one described by Carstensen

Figure 1—*Percent of parent compound decomposed as a function of time at 90°.*

and Musa (Fig. 6 of Ref. 3) was constructed for the studies at each temperature. The assembly was completely tight since it was fused by glass blowing and sealed under vacuum (<0.1 μm Hg). The entire assembly was placed in a thermostated mineral oil bath or, for lower temperatures, in a water bath. The pressure evolution was followed as a function of time with a cathetometer[2]. All pertinent volumes were determined by water weight calibration. With knowledge of the volumes, the pressures were converted to moles of gas, thus yielding a decomposition *versus* time curve (Fig. 1). The gas evolution eventually accounted for 100% decomposition.

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[1] This agent is known as RMI 14514 and was supplied by R. A. Parker and M. A. Zoglio, Merrell National Laboratories, Cincinnati, OH 45215.

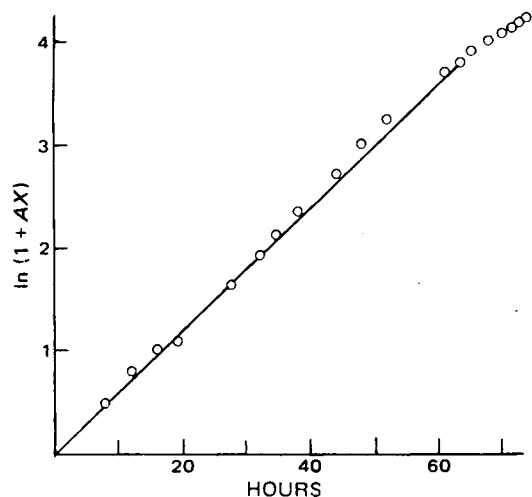[2] Model M-911, Gaertner Scientific Corp., Chicago, IL 60614.

Figure 2—*Data from Fig. 1 treated according to Eq. 3* (A = 70).

The data treatment (3–6) of the curve is as follows. If the amount is n moles and if there are x moles decomposed at time t, then x is present as liquid. If the solubility of parent compound in the liquid is S moles of RCOOH/mole of RH, then the amount of solid present is $n - x - Sx$; the rate equation then is:

$$dx/dt = -k_s(n - X - Sx) - k_l Sx \qquad \text{(Eq. 1)}$$

where k_s and k_l are solid and liquid first-order rate constants, respectively. If the mole fraction $X = x/n$ is used in place of moles decomposed, the equation becomes:

$$dX/dt = -k_s(1 - x - SX) - k_l SX \qquad \text{(Eq. 2)}$$

By integration:

$$\ln(1 + AX) = -\alpha t \qquad \text{(Eq. 3)}$$

where $A = \alpha/k_s$ and $\alpha = k_l S - k_s S - k_s$. The value of A is found by iteration, and linearization according to Eq. 3 is shown in Fig. 2. Once all solid has disappeared, the model no longer holds and simply reverts to solution kinetics as pointed out by Carstensen and Musa (3).

The values at four temperatures are shown in Table I. The least-squares fit for the Arrhenius plot (Fig. 3) is:

$$\ln k_s = (-38,650/R)(1/T) + 46.25 \qquad \text{(Eq. 4)}$$

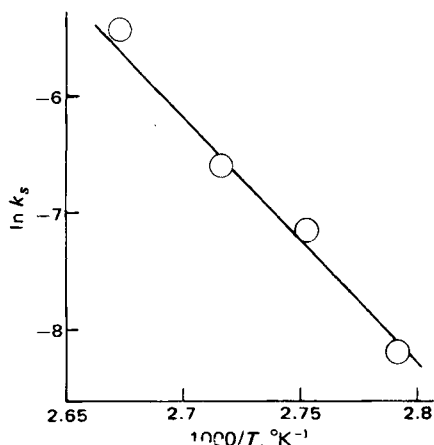with a correlation coefficient of -0.992. The activation

Figure 3—*Arrhenius data of decomposition rate constants, k_s, of the parent compound in the solid state (Table I).*

Table I—Parameter Values at Different Temperatures

Temperature	1000/T	A^a	α^b, hr^{-1}	$k_s{}^c$, hr^{-1}	ln k_s
85°	2.792	28	0.0070	0.00025	−8.094
90°	2.754	70	0.0594	0.00085	−7.070
95°	2.716	110	0.116	0.00151	−6.496
101°	2.673	175	0.571	0.00327	−5.723

^{a} The A denotes the iteration constant in Eq. 3. ^{b} The α denotes the slope of the line according to Eq. 3. ^{c} The k_s is the solid-state decomposition constant.

energy for k_s is high compared to usual solution kinetics (although within range) but is lower than that for, for instance, the solid-state decomposition of substituted benzoic (3) or salicylic (6) acids. Solid-state activation energies are extremely high (3–7, 9–13). When they are wholly dictated by physical propagation (type I), the energy of activation supersedes the normal range for solution kinetics by a factor of two to three. Type II reactions usually have intermediate activation energies.

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J. T. Carstensen [x]
Rohit C. Kothari
School of Pharmacy
University of Wisconsin
Madison, WI 53706

Structure–Activity Analysis of Hydrazide Monoamine Oxidase Inhibitors Using Molecular Connectivity

To the Editor:

Fulcrand *et al.* (1) recently analyzed a series of mono-amine oxidase inhibitors and found good correlations between pI_{50} values and electronic and steric parameters for 24 compounds. The methods of Hansch *et al.* (2) and Free and Wilson (3), as employed by Fulcrand *et al.* (1), were equally successful in correlating physical properties with