(d) **N-*n*-Octylethylenediaminetriacetic Acid.**—Sodium sulfate was fractionally precipitated by the addition of 300 ml. of absolute ethanol. The resulting filtrate was then evaporated under reduced pressure to half its original volume and allowed to stand in the cold. The desired triacetic acid, contaminated with a considerable amount of sodium sulfate, precipitated. Twelve recrystallizations from 90% ethanol yield 5 g. (15% of the theoretical amount) of N-*n*-octylethylenediaminetriacetic acid; 3.2 g. of nitrilotriacetic acid was isolated from the alcoholic mother liquor.

(e) **N-*n*-Dodecylethylenediaminetriacetic Acid.**—Sodium sulfate was fractionally precipitated by the addition of 300 ml. of absolute ethanol and allowing the solution to stand overnight in the cold. Further refrigeration of the mother liquor for four days resulted in the precipitation of the crude triacetic acid derivative. Three recrystallizations from a large volume of hot water yielded 3 g. of pure N-*n*-dodecylethylenediaminetriacetic acid. In addition, 3 g. of nitrilotriacetic acid was isolated from the sodium sulfate residues.

B. **Carboxymethylation of N-Benzylethylenediamine with Barium Cyanide.**—One liter of an aqueous solution containing 15 g. (0.1 mole) of N-benzylethylenediamine, 32.2 g. (0.17 mole) of barium cyanide and 31.5 g. (0.1 mole) of barium hydroxide octahydrate was heated to 40° on a water-bath. One hundred milliliters of an aqueous solution containing 0.37 mole of formaldehyde was added dropwise over a period of 20 hours with rapid stirring. A stream of air was bubbled through the reaction mixture to aid in the removal of ammonia.

The mixture was then treated with the stoichiometric amount of 50% H_2SO_4 and heated at reflux temperature for eight hours. The precipitated barium sulfate was allowed to settle overnight and filtered. The filtrate was evaporated to a small volume under reduced pressure and was then diluted with approximately 300 ml. of absolute ethanol. The small amount of barium sulfate which separated after standing overnight was filtered off, and this filtrate was concentrated to a total volume of approximately 150 ml. The N-benzyltriacetic acid separated upon cooling. After three recrystallizations from 90% ethanol a pure product was obtained. A mixed melting point with a sample of the triacetic acid formed by the former procedure showed no depression.

Potentiometric Titration Method.—Titrations were performed in a closed cell which was thermostated at 24.2 ± 0.1°. Presaturated nitrogen was bubbled slowly through the solution to maintain an inert atmosphere. The *p*H values were determined with the aid of a Beckman Model G *p*H meter equipped with glass and calomel electrodes standardized by the use of standard buffer solution. The sodium hydroxide was prepared carbonate free by the usual procedure. Titrations were performed on solutions containing initial amino acid concentrations of 2×10^{-3} *M* both in the absence and in the presence of an equimolar amount of cupric chloride and 10 times the amount of calcium chloride. The titration of the dodecyl derivative was performed on a suspension of the acid in 0.1 *N* KCl.

Spectrophotometric Method.—Measurements were performed in the ultraviolet region (220–350 mμ) with a Beckman model DU quartz spectrophotometer. Quartz cells were used and transmission readings were taken at 5 mμ intervals. All solutions were prepared by diluting a 10^{-3} *M* stock solution to the desired concentrations. The stock solution was prepared by dissolving the weighed quantity of acid in one-half the required volume of water, adding the stoichiometric quantity of standard sodium hydroxide to form the trisodium salt, and diluting to volume. Solution containing copper(II) and calcium(II) chelates were prepared in the same manner. All solutions were filtered before use.

Calculation of Stability Constants.—The calculation of the acid dissociation and complex formation constants was performed by the algebraic method described recently.[8] The final equation for the formation constants may be written

$$K = \frac{C_A - \beta[A^{-3}]}{[A^{-3}]\,(C_M + \beta[A^{-3}] - C_A)}$$

where C_A and C_M are the total concentrations of amino acid and metal ions, respectively, and K is the formation constant. $[A^{-3}]$ was calculated from the expression

$$[A^{-3}] = \frac{(3 - a)C_A - [H^+] + [OH^-]}{\dfrac{3[H^+]^3}{K_1K_2K_3} + \dfrac{2[H^+]^2}{K_2K_3} + \dfrac{[H^+]}{K_3}}$$

where K_1, K_2 and K_3 are the corresponding acid dissociation constants, and a denotes moles of standard base added per mole of amino acid, and

$$\beta = \frac{[H^+]^3}{K_1K_2K_3} + \frac{[H^+]^2}{K_2K_3} + \frac{[H^+]}{K_3} + 1$$

WORCESTER, MASS.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF SOUTHERN CALIFORNIA]

Derivatives of Sulfenic Acids. XXV. The Kinetics of the Reaction of 2,4-Dinitrobenzenesulfenyl Chloride with Cyclohexene[1]

BY DONALD R. HOGG AND NORMAN KHARASCH

RECEIVED JULY 5, 1955

Reaction of 2,4-dinitrobenzenesulfenyl chloride and cyclohexene in dry acetic acid yields only the 1:1 adduct, 2-chlorocyclohexyl 2′,4′-dinitrophenyl sulfide, and follows the rate expression, $-d[\text{ArSCl}]/dt = k[\text{ArSCl}]\,[\text{cyclohexene}]$. The values of k (mole/l.)$^{-1}$ sec.$^{-1}$, are 4.17×10^{-3}, 4.89×10^{-3}, 7.84×10^{-3} and 14.75×10^{-3}, at 15.3°, 17.6°, 25° and 35.2°, respectively. This gives 11.1 ± 0.5 kcal./mole for E_a and −33 cal./deg. for $\Delta S^{\ddagger}$. The values of k, (mole/l.)$^{-1}$ sec.$^{-1}$, for other solvents are 30.2×10^{-3}, 14.6×10^{-3}, 6.5×10^{-3} and 1.08×10^{-5}, for nitrobenzene, *sym*-dichloroethane, chloroform and carbon tetrachloride, in the order listed. These data are consistent with a mechanism previously suggested, which involves formation of a cyclic sulfonium ion intermediate as the rate-determining step.

From previous work it is known that 2,4-dinitrobenzenesulfenyl chloride (I) undergoes a general addition reaction with olefins,[2] that the additions to styrene and *p*-substituted styrenes, in dry acetic acid, are first order with respect to each reactant and are favored by electron-releasing *para* substituents in the styrene,[3,4] that the addition of the sulfenyl chloride to cyclohexene leads to the *trans* adduct[5] and that the reactions, in acetic acid, can be suitably formulated on the basis of a polar mechanism involving formation of an intermediate sulfonium ion as the rate-determining step.[3]

In continuing our studies of the kinetics and mechanism of the sulfenyl halide–olefin reaction, the kinetics of addition of I to cyclohexene, in acetic acid and in other solvents, have now been determined. Cyclohexene was selected for particular

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[1] Carried out under sponsorship of the Office of Ordnance Research, United States Army.

[2] N. Kharasch and C. M. Buess, THIS JOURNAL, **71**, 2724 (1949).

[3] W. L. Orr and N. Kharasch, *ibid.*, **75**, 6030 (1953).

[4] W. L. Orr and N. Kharasch, *ibid.*, **78**, 1201 (1956).

[5] A. J. Havlik and N. Kharasch, *ibid.*, **78**, 1207 (1956).

study because its reactions are of general interest and because it is accessible, easy to purify, symmetrical and shows a convenient reactivity over a wide range of conditions. These are also the factors which are expected to make it the convenient reference olefin for kinetic studies with other sulfenyl halides, in experiments designed to demonstrate the effects of changing the Ar and X groups, in ArSX, on the olefin–sulfenyl halide reaction.

The addition of I to cyclohexene, in dry acetic acid, was studied at 15.3°, 17.6°, 25° and 35.2°, as well as in carbon tetrachloride, chloroform, *sym*-dichloroethane and nitrobenzene, at 35.2°. The data for these runs, together with required details, are given in the Experimental part. The results suggest the following conclusions and discussion.

(1) Addition of I to cyclohexene in the various solvents leads to the same product, *trans*-1-chloro-2-(2′,4′-dinitrophenylthio)-cyclohexane,[5] and the reaction can be carried to quantitative completion if desired.

(2) The addition of I to cyclohexene, at 25°, in dry acetic acid, is fast and follows a second-order rate expression. At 25°, I adds to cyclohexene about 10 times as fast as to styrene and at about 3 times the rate with *p*-methylstyrene. The differences in rates appear to be governed almost entirely by the differences in activation energies, as shown in Table I, since the entropies of activation for the three reactions are identical, within limits of accuracy of the data. The data for the styrenes are from the papers of Orr and Kharasch.[3,4]

TABLE I

COMPARISON OF THE KINETIC PARAMETERS FOR THE REACTIONS OF 2,4-DINITROBENZENESULFENYL CHLORIDE WITH CYCLOHEXENE, STYRENE AND *p*-METHYLSTYRENE, IN ACETIC ACID, AT 25°

Olefin	$k \times 10^3$, (mole/l.)$^{-1}$ sec.$^{-1}$	E_a, kcal./mole	log A	$\Delta S^{\ddagger}$, cal./deg.
Cyclohexene	7.84	11.1	6.06	−32.7 ± 1
Methylstyrene	2.43	12.0	6.10	−32.2 ± 1
Styrene	0.737	12.9	6.34	−31.6 ± 1

The correspondence of the values for the entropies of activation may, of course, be fortuitous in the three instances of Table I and the determinations of the kinetic parameters for a series of related olefins is therefore planned for later work. If differences in the steric factors do not complicate the interpretations, as is indicated by the constancy of the entropy terms, the relative rates of reactions must also be in the order of increasing electron availability at the olefin bonds (*i.e.*, cyclohexene > *p*-methylstyrene > styrene). These relative rates of additions of I to olefins also appear to parallel those for epoxidation and bromination, suggesting that the same major factor (electron availability) also governs the rates of these reactions. Thus, the rate of epoxidation of cyclohexene, by peracetic acid at 25.8°, is also approximately 10 times that for styrene, the second-order velocity constants being 129 × 10^{-3} and 11.2 × 10^{-3} (mole/l.)$^{-1}$ sec.$^{-1}$, respectively.[6] More recent data by Lynch and Pausacker[7] for the peroxidation of cyclohexene and styrene by perbenzoic acid in benzene at 25° give 180 × 10^{-4} and 9.6 × 10^{-4}, (mole/l.)$^{-1}$ sec.$^{-1}$, as the respective, relative rate constants in this reaction. The corresponding values for E_a were 12.7 and 14.2 kcal./mole, and the attendant entropies of activation were given as −24.0 and −24.8 cal./deg. Evaluation of data for relative rates of bromination are complicated by the rapidity of the reactions, as well as by occurrence of reactions of kinetic orders higher than second. From the data of Robertson and co-workers,[8,9] however, who studied several olefins, the second-order velocity constant for the addition of bromine to cyclohexene, in acetic acid, is about three times that for styrene. In view of these possible relationships and because relative rate data with reagents as I is convenient to obtain, extension of the studies to a variety of olefins and ArSX reagents should have general as well as intrinsic interest (*cf.* also references 3 and 4).

(3) The effects of a series of solvents of increasing polarity on the rates of the reactions of I and cyclohexene were noted. In carbon tetrachloride, which is of the lowest polarity, the rate was quite slow but increased by a factor of about six hundred in passing to chloroform. The approximate relative rates (based on the second-order rate constants) for the different solvents are: carbon tetrachloride (1), chloroform (600), ethylene chloride (1400), acetic acid (1400) and nitrobenzene (3000). Thus, the rates were rapid in all solvents except carbon tetrachloride and—in contrast to the large effect in passing from the latter to chloroform—increased only about fivefold from chloroform to nitrobenzene. This change in rate with increasing polarity of the solvent is in agreement with a previously postulated,[2,3] polar mechanism for the addition of I to olefins.[10]

Experimental[11]

Reactants and Solvents.—Cyclohexene was extracted with aqueous ferrous sulfate solution,[12] dried and fractionated in a nitrogen atmosphere and from sodium metal, through a five-foot metal-packed column. This stock cyclohexene was kept over sodium. Before use, it was refluxed for 2 hr., while in contact with fresh sodium, and distilled; b.p. 82–82.5°, $n^{20}D$ 1.4463–1.4467. 2,4-Dinitrobenzenesulfenyl chloride[13] was recrystallized 4 to 6 times from dry carbon tetrachloride, using charcoal in the first two recrystallizations. Dry acetic acid (b.p. 118°) was

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[6] J. Stuurman, *Proc. Acad. Sci. Amsterdam*, **38**, 450 (1935); Thesis, Delft (1936); *cf.* also, Boeseken and Stuurman, *Rec. trav. chim.*, **56**, 1034 (1937); and D. Swern, THIS JOURNAL, **69**, 1692 (1947).

[7] B. M. Lynch and K. H. Pausacker, *J. Chem. Soc.*, 1525 (1955).

[8] P. W. Robertson, J. H. Heyes and B. E. Swedlund, *ibid.*, 1014 (1952).

[9] I. Ting and P. W. Robertson, *ibid.*, 628 (1947).

[10] The runs for the reactions of I and cyclohexene in carbon tetrachloride and chloroform, which are recorded in the Experimental section, gave excellent second-order plots (*cf.*, *e.g.*, Fig. 2). With the sulfenyl chloride in considerable excess, however, a first-order process (independent of the olefin concentration) has also been observed for the reaction of I and cyclohexene in these solvents. This phenomenon, which is being studied separately, is reminiscent of the finding of both first- and second-order processes in the reaction of I with acetone, in methyl acetate as solvent; *cf.* M. M. Wald and N. Kharasch, subsequent paper of this series. *Cf.* also abstracts of the Organic Division, American Chemical Society Meeting, New York, Sept., 1954.

[11] The microanalyses were made by Mr. W. J. Schenck; melting points are not corrected.

[12] Old cyclohexene gave a very vigorous, exothermic reaction in this process.

[13] N. Kharasch, G. I. Gleason and C. M. Buess, THIS JOURNAL, **72**, 1796 (1950).

made by refluxing reagent grade acid (1000 ml.) with acetic anhydride (100 ml.) for 2 days, then fractionating through a four-foot column packed with glass helices. Dried, reagent grade carbon tetrachloride was fractionated from anhydrous calcium oxide, b.p. 77–77.2°, $n^{20}D$ 1.4443–1.4445. Nitrobenzene was dried over phosphorus pentoxide, purified twice by freezing and discarding the non-frozen portion and distilling under reduced pressure. The product was pale lemon-yellow in color, $n^{26}D$ 1.5490, $n^{27}D$ 1.5482. Chloroform was dried over calcium chloride, then phosphorus pentoxide and fractionated—excluding light and oxygen—b.p. 62°, $n^{25}D$ 1.4430. The pure solvent was free of contaminants which would give a positive test for chloride with silver nitrate solution and *p*-dimethylaminoazobenzene (test for HCl) but did not keep well, as shown by strong positive tests for such contaminants after 4 days. Before use, air was expelled from all solvents by sweeping with dry nitrogen for about 20 min.

Product Isolation.—The recorded[5] adduct, m.p. 119° after chromatographing on alumina, was obtained in 93.3% yield by reaction of cyclohexene and I in acetic acid. The yield of crude product was quantitative. The identical product was also obtained from the other solvents.

Anal. Calcd. for $C_{12}H_{13}ClN_2O_4S$: C, 45.50; H, 4.14; Cl, 11.20; N, 8.84. Found: C, 45.70; H, 4.28; Cl, 11.02; N, 8.61.

Kinetic Runs.—The general procedure for runs in acetic acid is given in reference 3. In other solvents, the iodometric titration of I was modified by first adding 15 ml. of dry acetic acid to the sodium iodide, swirling twice, then adding the 10-ml. aliquot of the reaction solution.[14] Successive blanks during the run showed some increase in the quantity of iodine released, making it necessary to estimate a reasonable average blank for each run. In blanks, 10 ml. of solvent rather than of reaction mixture was used. The runs in carbon tetrachloride were made in sealed ampoules, using 12–15 ml. of reaction mixture in each, and pipetting the 10-ml. aliquots from the ampoules. The runs in chloroform and nitrobenzene were conducted in shielded flasks to exclude light. In chloroform, especially, it was difficult to obtain a reproducible blank. Successive blanks throughout the run showed some increase in the quantity of iodine released, making it necessary to approximate a reasonable average blank for each run.

Results in Acetic Acid.—Data for the runs in acetic acid are summarized in Table II and details for a typical run are listed in Table III. From the data of Table III, an excellent second-order plot (not shown) resulted. The runs at other temperatures, in acetic acid, closely resembled this run, although in some cases—probably because of errors in initial timing and blank corrections—the plots of log $b(a - x)/a(b - x)$ did not pass through the origin but intersected the time abscissa at distances up to 3 minutes. In these cases, calculations were made with this intercept as the origin.

All the runs were followed to at least 73–80% completion. In determining the mean values of the constants for Table II, points below 10–15% and above 80–85% were excluded. No definite tendency to either low or high values of *k* was noticed for points in these regions and their general scattering is ascribed to increased experimental errors at low and high percentage reaction. From the graph of log $b(a - x)/a(b - x)$ *vs.* time, the best straight line was estimated, and *k* was calculated from the slope of this line. This was the value taken for the individual runs, and its value was generally within 1% of the mean values of *k*, calculated from the experimental zero point (see above) to each successive point. The uncertainties in the values of *k* were determined by noting the deviations between the values of *k* for the individual points and the mean values of *k*. The initial concentration of cyclohexene was calculated from the known weight of the olefin introduced into the reaction mixture and that of I was determined by titrating aliquots of the freshly prepared stock solution of I. In the run at 15.3°, the final point was taken at 73% completion of reaction, at which time the solvent began to solidify, but no complexities resulting from this were noted. The plot of log *k vs.* 1/*T* (Fig. 1), for the runs in acetic acid, gives an excellent linear relation, indi-

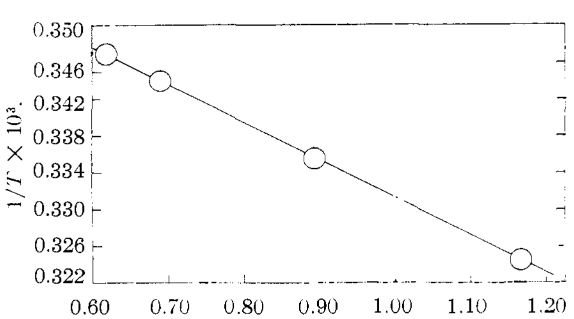

Fig. 1.—Plot of log ($k \times 10^3$) *vs.* $1/T \times 10^2$ for the reaction of 2,4-dinitrobenzenesulfenyl chloride with cyclohexene, in acetic acid.

TABLE II

SUMMARY OF RATE RUNS AT FOUR TEMPERATURES, IN ACETIC ACID, FOR THE REACTION OF 2,4-DINITROBENZENESULFENYL CHLORIDE AND CYCLOHEXENE

Run	Mole/l. of cyclohexene	Mole/l. of ArSCl	$k \times 10^3$, (mole./l.)$^{-1}$ sec.$^{-1}$	Mean value of $k \times 10^3$	°C.
1	0.0435	0.0711	7.57 ± 4%		
2	.0682	.0358	7.95 + 7% − 11%	7.84 ± 3.4%	25.0 ± 0.1
3	.0376	.0176	7.75 ± 7%		
4	.0396	.0374	8.10 ± 4.5%		
5	.0258	.0188	14.4 ± 8%		
6	.0201	.0226	15.3 + 3% − 6%	14.75 + 4% − 3%	35.2 ± 0.1
7	.0216	.0226	14.8 ± 8%		
8	.0201	.0450	14.5 ± 5%		
9	.0760	.0284	4.89 ± 3%	4.89 ± 3%	17.6 ± 0.1
10	.0729	.0294	4.17 ± 4%	4.17 ± 4%	15.3 ± 0.1

TABLE III

DATA FOE A TYPICAL RUN IN ACETIC ACID[a]

Time, min.	Concn. ArSCl $(a - x)$	Concn. cyclohexene $(b - x)$	$\frac{b(a - x)}{a(b - x)}$	log $\frac{b(a - x)}{a(b - x)}$	$k \times 10^3$, (mole/l.)$^{-1}$ sec.$^{-1}$	
0	18.47	8.83[b]				
3	17.50	7.86	1.0644	0.02710	14.701	
7.5	16.40	6.76	1.1598	.06439	13.969	
13.5	15.24	5.60	1.3010	.11429	13.775	
19.25	14.11	4.47	1.5090	.17871	15.106	
24.5	13.64	4.00	1.6302	.21225	14.196	
29.75	13.08	3.44	1.8178	.25954	14.195	
34.75	12.58	2.94	2.0456	.31083	14.554	
39.75	12.30	2.66	2.2106	.34452	14.102	
47	11.75	2.11	2.6623	.42525	14.774	
55	11.56	1.92	2.8784	.45915	13.623	
66.5	10.94	1.30	4.0232	.60457	14.793	85.2% reacn.
81	10.33	0.69	6.0969	.78510	15.77[c]	
104	10.20	0.56	8.7078	.93991	14.70[c]	93.6% reacn.
154.25	9.95	0.31	15.3446	1.18596	12.5[c]	96.5% reacn.

[a] Run 8 of Table I. [b] The molar concentrations are stated in terms of the equivalent volume (ml.) of 0.02447 *N* sodium thiosulfate solution. [c] The mean value of $k \times 10^3$, omitting these points, is 14.34 ± 5%.

TABLE IV

A SUMMARY OF THE RUNS AT 35.2 ± 0.1° IN SOLVENTS OTHER THAN ACETIC ACID

Run	Solvent	Mole/l. of cyclohexene	Mole/l. of ArSCl	k, (mole/l.)$^{-1}$ sec.$^{-1}$
11	CCl_4	0.1225	0.0456	$(1.05 \pm 10\%) \times 10^{-5}$
12	CCl_4	.115	.046	$(1.11 \pm 8\%) \times 10^{-5}$
13	$CHCl_3$	.074	.0301	$(6.68 \pm 5\%) \times 10^{-3}$
14	$CHCl_3$	.074	.0298	$(6.38 \pm 15\%) \times 10^{-3}$
15	CH_2ClCH_2Cl	.0736	.0302	$(1.46 \pm 7\%) \times 10^{-2}$
16	CH_2ClCH_2Cl	.0501	.0302	$(1.41 \pm 12\%) \times 10^{-2}$
17	CH_2ClCH_2Cl	.0250	.0604	$(1.59 \pm 12\%) \times 10^{-2}$
18	$C_6H_5NO_2$	.0292	.0292	$(3.02 \pm 14\%) \times 10^{-2}$

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[14] *Cf.* N. Kharasch and M. M. Wald, *Anal. Chem.*, **27**, 996 (1955).

cating that the changes in the character of the solvent at temperatures close to its freezing point are not sufficiently serious to influence its function in this reaction. The slope of this line gives 11.1 ± 0.5 kcal./mole for the activation energy, E_a, from which the calculated values of $\Delta F^{\ddagger}$ and $\Delta S^{\ddagger}$ are 20.3 kcal./mole and −32.7 ± 1 cal./deg., respectively.

TABLE V

DATA FOR THE REACTION OF 2,4-DINITROBENZENESULFENYL CHLORIDE AND CYCLOHEXENE, IN CHLOROFORM, AT 35.2° (RUN 13)

Min.	Ml. of 0.0305 N thiosulfate equivalent concn. (moles/l.)[a] Cyclohexene	ArSCl	$\log \frac{b(a-x)}{a(b-x)}$	$k,^b \times 10^3$, (moles/l.)$^{-1}$ sec.$^{-1}$
0	24.47	9.95		
8.5	22.52	8.00	0.05867	6.398
19	20.58	6.06	.14014	6.609
31	18.93	4.41	.24190	6.919
41.5	18.14	3.62	.30911	6.577
53.5	17.37	2.85	.39414	6.488
62	16.86	2.34	.46690	6.623
74	16.20	1.68	.59339	7.043
92.5[c]	15.77	1.25	.71011	6.734

[a] The initial concentrations were a = 0.0301 mole/l. for the sulfenyl chloride (I) and b = 0.074 mole/l. for cyclohexene. [b] The values of k are calculated from 0.5 min. as the origin (*Cf*, text). The mean value of k for this run is (6.67 ± 5%) × 10^{-3} (mole/l.)$^{-1}$ sec.$^{-1}$; the graphical value from Fig. 2 is 6.68 × 10^{-3} (mole/l.)$^{-1}$ sec.$^{-1}$. [c] This point represents 87.4% complete reaction.

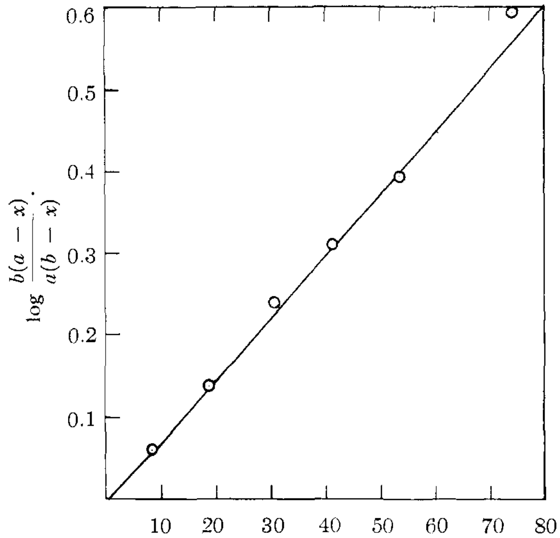

Fig. 2.—Plot of a typical run (no. 13, Table IV) for the reaction of 2,4-dinitrobenzenesulfenyl chloride with cyclohexene, in chloroform, at 35.2°, showing adherence to the second-order rate expression.

The data for the runs in other solvents are summarized in Table IV. The accuracy of these runs is lower than in the acetic acid studies, for the titration end-points were generally not as distinct and the rate in nitrobenzene was quite rapid, causing increased timing errors. The runs in carbon tetrachloride, which lasted up to 15 days, were made with aliquots, in sealed ampoules, to minimize evaporation and reactions with moisture and air. This precaution was not necessary for the runs in the other solvents, all of which gave quantitative reactions in a matter of hours. Run 15, in *sym*-dichloroethane, gave equally good second-order plots, whether or not the blank correction was used in calculating the concentration of I throughout the run. To conform with the other runs, however, the value of k in Table IV includes the blank correction, the value of k without using the blank correction being (1.27 ± 7%) × 10^{-2} (mole/l.)$^{-1}$ sec.$^{-1}$. The data for one of the runs in chloroform are given in Table V and plotted in Fig. 2. Because of the doubtful validity of the blank in solvents other than acetic acid, the values of k, in Table IV, are only of relative, rather than absolute, value but they clearly show the marked effect which increasing polarity of the solvents has on the rates (*cf.* Discussion).

UNIVERSITY PARK, LOS ANGELES 7, CALIF.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF ROCHESTER]

Studies on Thioesters Related to Coenzyme A. A Kinetic Study of Aminolysis and Hydrolysis of β-(N-Methylacetamino)-ethyl Thioacetate, N,S-Diacetylaletheine and γ-Acetaminopropyl Thioacetate[1]

BY D. STANLEY TARBELL AND DONALD P. CAMERON[2]

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The synthesis of β-(N-methylacetamino)-ethyl thioacetate and of γ-acetaminopropyl thioacetate is described. Rates of alkaline hydrolysis and of aminolysis by *n*-butylamine of these thioesters and of N,S-diacetylaldetheine in aqueous solution at 0° have been measured; the kinetics of the reactions have been discussed. The above thioesters, containing some of the structural features of coenzyme A, do not differ greatly among themselves or with ethyl thioacetate and β-acetaminoethyl thioacetate, with respect to the reactivity of the thioester grouping under the conditions specified.

The increasing recognition of the central role of coenzyme A in enzymatic processes has made detailed study of the thioester grouping desirable.[3] It was shown recently[4] that the rates of aminolysis and of hydrolysis in aqueous solution for ethyl thioacetate (I) and β-acetaminoethyl thioacetate (II) were not markedly different; hence the acet-

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[2] Predoctoral Fellow of the United States Public Health Service.

[3] For some recent studies on the rates of hydrolysis of simple thioesters, *cf.* P. N. Rylander and D. S. Tarbell, THIS JOURNAL, **72**, 3021 (1950); B. K. Morse and D. S. Tarbell, *ibid.*, **74**, 416 (1952); L. H. Noda, S. A. Kuby and H. A. Lardy, *ibid.*, **75**, 913 (1953); F. J. McQuillin and J. Stewart, *J. Chem. Soc.*, 2966 (1955); J. T. G. Overbeek and V. V. Koningsberger, *Koninkl. Nederl. Akademie van Wetenschapen-Amsterdam*, **57B**, 311, 465 (1954); **58B**, 49 (1955). Among other recent studies on thioesters, see M. J. Cronyn, M. P. Chang and R. A. Wall, THIS JOURNAL, **77**, 3031 (1955); R. Schwyzer, *Helv. Chim. Acta*, **36**, 414 (1953); T. Wieland and E. Bokelmann, *Ann.*, **576**, 20 (1952); J. C. Sheehan and C. W. Beck, THIS JOURNAL, **77**, 4875 (1955).

[4] P. J. Hawkins and D. S. Tarbell, *ibid.*, **75**, 2982 (1953).