acetone or alcohol resulted in recovery of 80–90% of the chloromethyl benzoate.

***p*-Tolylsulfonylcarbinyl *p*-Toluenesulfonate.**—A solution of 19.7 g. of the carbinol I in 35 ml. of dry dioxane was slowly poured with cooling into 30 ml. of dioxane containing 9.5 g. of pyridine and 22.8 g. of *p*-toluenesulfonyl chloride. The mixture, after standing for ten days, was poured into water and an ether extract washed with aqueous sodium bicarbonate and water. The ether contained 17.24 g. (48%) of solid, m.p. 45–58°, which upon recrystallization from petroleum ether–benzene gave 1.01 g. (3%) of the presumed tosylate, m.p. 84–86°. Further recrystallization gave an unstable crystalline solid with a constant m.p. of 86–88°.

Anal. Calcd. for $C_{15}H_{16}O_5S_2$: S, 18.84. Found: S, 18.79.

The mother liquor yielded 11.9 g. (33%) of material which seemed to be the crude tosylate, m.p. 43–51°, undepressed by the analytically pure sample. Reduction with lithium aluminum hydride gave di-*p*-tolyl disulfide and *p*-thiocresol rather than methyl *p*-tolyl sulfone which reported reductions of tosylates to hydrocarbons[9] might lead one to expect.

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[9] J. Strating and H. J. Backer, *Rec. trav. chim.*, **69**, 638 (1950); H. Schmid and P. Karrer, *Helv. Chim. Acta*, **32**, 1371 (1949).

DEPARTMENT OF CHEMISTRY
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RECEIVED JULY 20, 1951

Tetramethylthiophene and Tetramethylfuran

BY RUSSELL GAERTNER AND RICHARD G. TONKYN

In connection with an unsuccessful attempt to use a simple thiophene[1] as a diene in the Diels–Alder reaction,[2] useful syntheses for tetramethylthiophene (I) and tetramethylfuran (II) were developed.

2,5-Dimethylthiophene was chloromethylated to give 3,4-bis-(chloromethyl)-2,5-dimethylthiophene, which was reduced to I by lithium aluminum hydride. Maleic anhydride did not react with I, even in boiling nitrobenzene, but added to II at room temperature. The furan (II) was obtained by dehydration of 3,4-dimethyl-2,5-hexanedione with acetic anhydride and zinc chloride. Acetonylacetone was also converted to 2,5-dimethylfuran by these reagents[3] (71% yield).

Experimental[4]

3,4-Bis-(chloromethyl)-2,5-dimethylthiophene.—To a solution of 72.4 g. of *s*-trioxane in 75 ml. of concd. hydrochloric acid which had been saturated below 50° with hydrogen chloride was added dropwise and with stirring 30 g. of 2,5-dimethylthiophene. The blue mixture was stirred for two hours, diluted with three volumes of water, and extracted with ether and petroleum ether. The extracts were washed successively with dilute hydrochloric acid, water, 5% sodium bisulfite, water, and dilute sodium hydroxide. The solid obtained by evaporation of the solvents was recrystallized from hexane by cooling the solution in the refrigerator. Colorless needles (28 g., 50% yield) were obtained; m.p. 73°.

The twice recrystallized material was sublimed *in vacuo* before analysis; m.p. 73.0–73.4°.

Anal. Calcd. for $C_8H_{10}Cl_2S$: C, 45.94; H, 4.82. Found: C, 46.04; H, 4.86.

The product reacted immediately with alcoholic silver nitrate. It did not form a Grignard reagent in the "cyclic reactor"[5] as evidenced by the negative Gilman color test.[6]

Tetramethylthiophene (I).—Reduction[7] of 13 g. of the chloromethyl compound with 6.3 g. of lithium aluminum hydride yielded 5.8 g. (67%) of colorless I[8]; b.p. 74–79° (15 mm.); $n^{20}\text{D}$ 1.5199. An attempted low-pressure hydrogenation of the halide over platinum oxide and then 10% palladium-on-charcoal was unsuccessful; the recovered material in dioxane was reduced with stannous chloride[9] to give I in 54% yield. The action of phosphorus pentasulfide on 3,4-dimethyl-2,5-hexanedione[10] gave I in only 8% yield in a single small run. No product could be detected in mixtures of I with a tenfold excess of maleic anhydride in boiling benzene after four days or in boiling nitrobenzene after four hours.

Tetramethylfuran (II).—A mixture of 15 g. of 3,4-dimethyl-2,5-hexanedione,[10] 12 g. of acetic anhydride and 0.5 g. of anhydrous zinc chloride was heated under reflux for three hours after the initial exothermic reaction subsided. The mixture was made alkaline with 6 *N* sodium hydroxide and distilled with steam. The II[11] weighed 6.5 g. (49%); b.p. 145–148° (748 mm.); $n^{20}\text{D}$ 1.4550.

By a similar procedure, 114 g. of acetonylacetone, 112 g. of the anhydride and 1 g. of zinc chloride gave 69 g. (71%) of 2,5-dimethylfuran[12]; b.p. 92.5–94°; $n^{20}\text{D}$ 1.4470.

A yellow solution of 3 g. of II and 3.2 g. of maleic anhydride in 30 ml. of absolute ether was allowed to stand at room temperature overnight and then cooled at −15° for 24 hours. After being recrystallized from petroleum ether–ether, the yellow crystals gave white needles (3.2 g., 64%); m.p. 95–96°. They sublimed readily at 2 mm.; m.p. 95.8–96.6°.

Anal. Calcd. for $C_{12}H_{12}O_4$: C, 64.85; H, 6.35. Found: C, 65.00; H, 6.52.

The adduct, presumably tetramethyl-3,6-endoxotetrahydrophthalic anhydride, absorbed about a mole of hydrogen over platinum oxide.

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[1] Only highly arylated, fused thiophenes have been found to add maleic anhydride as do dienes; for a summary, see Kloetzel in Adams, "Organic Reactions," Vol. IV, John Wiley and Sons, Inc., New York, N. Y., 1948, pp. 36–37.

[2] Alkylated naphthalenes were reported by Kloetzel, *et al.*, This Journal, **72**, 273, 1991 (1950), to add maleic anhydride across the 1- and 4-positions in the substituted ring; it seemed likely that a similar effect might operate in the thiophene series.

[3] The use of acetic anhydride in this dehydration is apparently novel and was suggested by the observation of Hurd, Roach and Edwards, *ibid.*, **66**, 2013 (1944), that ketene effects this conversion.

[4] Melting points are corrected; boiling points are not. Microanalyses were by Micro-Tech Laboratories, Skokie, Illinois. Properties of known compounds agreed satisfactorily with those in the listed references.

[5] Under similar conditions 2-thenyl chloride forms high yields of Grignard reagent: *cf.* Gaertner, This Journal, **73**, 3934 (1951).

[6] Gilman and Schulze, *ibid.*, **47**, 2002 (1925); Gilman and Heck, *ibid.*, **52**, 4949 (1930).

[7] Johnson, Blizzard and Carhart, *ibid.*, **70**, 3664 (1948).

[8] Zelinsky, *Ber.*, **21**, 1835 (1888).

[9] Wood and Fieser, This Journal, **62**, 2674 (1940).

[10] Moore, *J. Chem. Soc.*, 236 (1951).

[11] Willstätter and Clarke, *Ber.*, **47**, 308 (1914).

[12] v. Auwers, *Ann.*, **408**, 271 (1915).

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RECEIVED JULY 16, 1951

Streaming Birefringence in Aqueous Solutions of Poly-4-vinyl-*n*-butylpyridinium Bromide

BY RAYMOND M. FUOSS WITH RUDOLF SIGNER

Previous work[1] on polyelectrolytes suggests that the configuration of charged macromolecules is a function of the concentration: at moderate concentration, many counter ions are held in the vicinity of the polyion by electrostatic attraction, with the result that the net charge per macroion is small, and the latter can assume approximately the statistical coil configuration of a neutral polymer. On dilution, counter ions escape into the bulk of the solvent between polyions, thereby increasing the net charge, with the result that intramolecular repulsion causes the coil to expand, and in the limit of infinite dilution, to assume a rod-like configuration. Measurement of streaming bire-

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[1] R. M. Fuoss and G. I. Cathers, *J. Polymer Sci.*, **2**, 12 (1947); R. M. Fuoss and W. N. Maclay, *ibid.*, **6**, 305 (1951).

fringence[2] offers a direct experimental test of this model. We report herewith the results of some preliminary experiments on the streaming birefringence of aqueous solutions of poly-4-vinyl-*n*-butylpyridinium bromide.

The salt was prepared by addition of *n*-butyl bromide to a fraction (44 H) of polyvinylpyridine which has already been described.[3] Measurements were made at 20° at velocity gradients from 850 to 20000 sec.$^{-1}$ over the concentration range 0.005–0.4 g. salt/100 ml. solution. In order to avoid possible errors due to adsorption of polyelectrolyte on the steel walls of the cell, the cell[4] was rinsed with three portions of solution before being finally filled for the measurements in the low range of concentration. The experimental results are summarized in Figs. 1–3.

In Fig. 1, the intensity of birefringence is plotted

$$i = n_\gamma - n_\alpha = \lambda\Delta/180d$$

against the velocity gradient G. Here, n_γ and n_α are the indices of refraction of the optically equivalent ellipsoid which represents the solute, $\lambda = 589$ mμ (sodium light), $d = 4.65$ cm. (the length of the light path in the solution) and Δ is the maximum rotation of the plane of polarization by the sheared solution. The latter is obtained experimentally as the rotation of the analyzer necessary to give equally illuminated half-fields when the radius of the rotator is set 45° away from the position where the half-fields are equally bright for stationary and moving rotor. Our solutions all showed negative birefringence, *i.e.*, n_γ makes an angle between 45° and 90° with the geometrical major axis of the ellipsoid hydrodynamically equivalent to the solute molecules. This result would be expected because the optically effective pyridine groups are approximately perpendicular to the carbon chain of the polymer. As Fig. 1 shows, the strength of the birefringence increases linearly at first with increasing gradient. (In order to avoid confusion, the data for 0.414 and 0.103 g./100 ml. are omitted in Fig. 1.) As the gradient increases, however, the curves become concave down, and appear to be approaching an asymptotic limit which would correspond to maximum orientation. In the lower range of concentrations, the limit appears to be approximately proportional to concentration. If orientation angle ψ is plotted against gradient, curves are obtained which are concave toward the gradient axis; the curves, of course, start at $\psi = 135°$ for zero gradient, with an initial slope which depends on concentration. Our data were not sufficiently precise to determine $(d\psi/dG)_{G=0}$, although they clearly show that $(d\psi/dG)_{G=0}$ goes through a maximum as a function of concentration between 0.1 and 0.2 g./100 cc. The largest observed value of ψ was 166° for $c = 0.00514$ at $G = 20000$ sec.$^{-1}$. The dependence of ψ on concentration for $G = 6655$ sec.$^{-1}$ is shown in Fig. 2A.

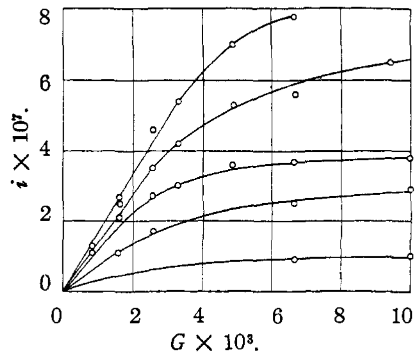

Fig. 1.—Dependence of birefringence on concentration and gradient; top to bottom, $c = 0.207$, 0.0516, 0.0255, 0.0128, 0.0051 g./100 cc.

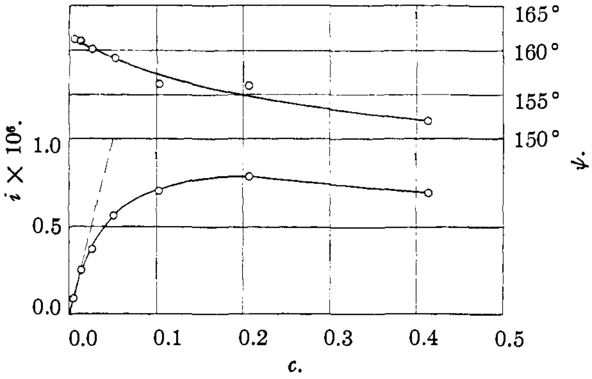

Fig. 2.—Dependence of orientation (A, ordinates right) and intensity of birefringence (B, ordinates left) on concentration for $G = 6655$ sec.$^{-1}$

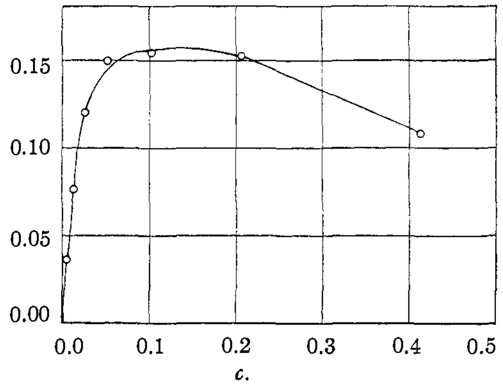

Fig. 3.—Dependence of $s = -10^9(n_\gamma - n_\alpha)/G$ at $G = 0$ on concentration.

The most interesting result of the experiments is shown in Figs. 2B and 3: the ***intensity of birefringence goes through a maximum as a function of concentration.*** In Fig. 2B, i is plotted against concentration for $G = 6655$. At 0.414 g./100 cc., i equals 0.70×10^{-6}; as seen in the figure, i slowly increases on dilution, reaching a maximum just under 0.2 g./100 ml. On further dilution, i approaches zero as c approaches zero, with a very steep initial slope. This behavior is in marked contrast to most substances previously investigated, which exhibit a concave-up i–c curve. If we plot the initial slopes of the i–G curves of Fig. 1 against concentration, we obtain Fig. 3, which shows that the maximum in the i–c curves persists down to the limit of zero gradient. In fact, as ordinate in Fig. 3, one really should use $(n_\gamma - n_\alpha)/G\eta$, where η is the viscosity of the solution; since the viscosity[5] of polyelectrolyte solutions

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(2) R. Signer, *Z. physik. Chem.*, **A150**, 257 (1930).

(3) E. B. FitzGerald and R. M. Fuoss, *Ind. Eng. Chem.*, **42**, 1603 (1950).

(4) A. Wissler, Thesis, Bern, 1940.

(5) R. M. Fuoss and U. P. Strauss, *Ann. N. Y. Acad. Sci.*, **51**, 836 (1949).

increases rapidly with increasing concentration, the maximum in the theoretically significant $(i/G\eta)_{G=0}$–c curve would be much sharper than that of the $(i/G)_{G=0}$ c curve of Fig. 3. According to theory,[6,7] $(i/G\eta)_0$ should be proportional to concentration for molecules of fixed geometry. The fact that $(i/G)_0$ is not a linear function for our polyelectrolytes is, therefore, experimental evidence that the average shape of the polyelectrolyte depends on the total concentration.

The curve of Fig. 3 approximates linearity with a high slope at zero concentration; we ascribe this to a rod-like configuration of the polyelectrolyte at low concentrations, corresponding to a very small rotatory diffusion constant; as concentration increases, association of counter ions to the polyion neutralizes increasingly more of its total charge, thus reducing intramolecular repulsion, and permitting the molecule to approach the statistical coil which has a larger diffusion constant.

A final test of the hypothesis that polyelectrolyte configuration is determined by electrostatic forces was made by measuring a solution containing 0.193 g. of polysalt and 0.95 g. of potassium bromide in 100 cc. The polyelectrolyte concentration is that corresponding to the maximum birefringence but a large excess (12 times stoichiometric equivalence) of counter ions is now present. We would expect this excess of counter ions to neutralize (electrostatically) the polyelectrolyte and then the resulting structure should shrink in volume to a rather compact spherical particle due to intramolecular attraction of the sort which stabilizes an ordinary ionic crystal. For table angles of 40, 60, 80, 100 and 120°, the following values of analyzer displacements necessary for equally bright half-fields were observed at a gradient of 20,000 sec.$^{-1}$: +0.1°, −0.3°, 0.0°, −0.5°, −0.2°. No trace of streaming birefringence is visible; by way of comparison, the solution containing 0.207 g. polysalt/100 ml. gave a maximum analyzer displacement of 1.8° at a gradient of only 850 sec.$^{-1}$. The birefringence data thus completely confirm the conclusions[5] which were deduced from the viscosities of solutions of these salts.

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(6) C. Sadron, *J. chim. phys.*, **36**, 78 (1939).

(7) A. Peterlin and H. A. Stuart, *Z. Physik*, **112**, 1 (1939).

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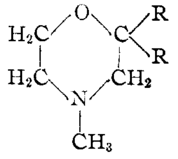
4-Methyl-2,2-diarylmorpholines

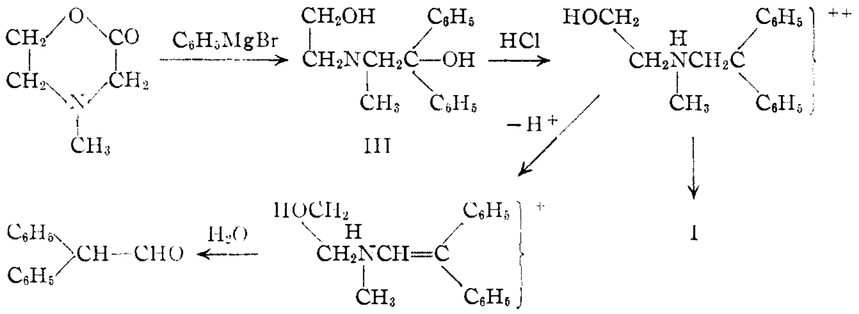
BY T. A. GEISSMAN, MURRAY BASSIN AND ERNEST J. ZEILBERGER

The recent description of the preparation of 4-methyl-2,2-diphenylmorpholine (I) by the reduction of 3-keto-4-methyl-2,2-diphenylmorpholine[1] prompts us to report our preparation of I, which may be considered as a cyclic form of the antihistaminic β-dimethylaminoethyl benzhydryl ether ("Benadryl" base), and of the *p*-tolyl analog (II) by a procedure different from that used by the English workers.



I, R = C_6H_5
II, R = *p*-$C_6H_4CH_3$

The reaction of the lactone of N-methyl-N-β-hydroxyethyl-glycine[2] with phenylmagnesium bromide and with *p*-tolylmagnesium bromide led in the first case to 1,1-diphenyl-2-(methyl-β-hydroxyethylamino)-ethanol (III). The corresponding di-*p*-tolyl compound was isolated but not characterized, being converted directly into II. The carbinol III showed a surprising reluctance to cyclize to I: it could be distilled at 10 mm. without change, but upon boiling with 6 *N* hydrochloric acid it was converted slowly into the morpholine. The structures of the compounds were demonstrated by (a) the formation of diphenylacetaldehyde from III during the treatment with acid, and (b) the formation of benzophenone from I and of benzophenone-4,4′-dicarboxylic acid from II on oxidation.



Compound I, when tested for its activity against aerosolized histamine in guinea pigs, was found to be devoid of activity up to a dose level of 20 mg./kg.[3]

Experimental

4-Methylmorpholone-2 was prepared as described by Kiprianov.[2]

1,1-Diphenyl-2-(methyl-β-hydroxyethylamino)-ethanol (III).—To the Grignard reagent prepared from 118 g. of bromobenzene in ether was added slowly an ether solution of 35 g. of 4-methylmorpholone-2. After an hour refluxing the mixture was decomposed with iced sulfuric acid and the ether layer separated. The ether solution was washed with dilute sulfuric acid and the combined aqueous solutions were basified with dilute sodium hydroxide. The colorless crystalline product which separated was recrystallized from ether–petroleum ether and from ethanol. It formed colorless prisms (31 g.), m.p. 110–111°.

Anal. Calcd. for $C_{17}H_{21}O_2N$: C, 75.22; H, 7.82. Found: C, 75.32, 75.43; H, 7.87, 7.82.

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(1) A. L. Morrison, R. F. Long and M. Königstein, *J. Chem. Soc.*, 952 (1951).

(2) A. Kiprianov, *Ukrain. Khem. Zhur.*, **4**, Sci. pt., 231 (1929); *C. A.*, **24**, 1084 (1930).

(3) The authors are indebted to Dr. E. J. Fellows, Smith, Kline and French Laboratories, for the pharmacological tests.