Anal. Calcd. for $C_{17}H_{15}O_4N_8S$: N, 11.76. Found: N, 11.8.

2-(o-Sulfanilamidophenyl)-oxazole.—The preceding acetyl derivative was hydrolyzed by refluxing the substance with twenty-five times its weight of 12% hydrochloric acid for forty minutes. By neutralization with ammonium hydroxide the product was precipitated in 80% yield. On recrystallization from 65% alcohol, using decolorizing charcoal, white prisms were obtained; m. p. 172.5- 173.5° .

Anal. Caled. for $C_{15}H_{13}O_3N_3S$: C, 57.13; H, 4.16; N, 13.33. Found: C, 57.2; H, 4.32; N, 13.4.

2-Phenyloxazole.—To a solution of 1.3 g. (0.0081 mole)of II in 20 cc. of 18% hydrochloric acid, cooled to 0-10°, was added with stirring 0.585 g. (0.0085 mole) of sodium nitrite in 5 cc. of water. After standing fifteen minutes at 0-10°, there was added 15 cc. of 50% hypophosphorous acid. The reaction mixture was placed in an icebox for eight hours and then let stand overnight at room temperature. The solution was cooled in ice and made basic with 20% sodium hydroxide solution. An inorganic precipitate was filtered and washed with ether. The filtrate was extracted with ether and the ether extracts dried over anhydrous potassium carbonate. After removal of the ether, the residue was distilled from an oil-bath. There was obtained 0.25 g. (21%) of a colorless oil; b. p. $225-228^{\circ}$ (760 mm.), (oil-bath at 270°). The substance had a pronounced odor, somewhat resembling methyl salicylate.

Anal. Calcd. for C₉H₇ON: C, 74.47; H, 4.86; N, 9.65. Found: C, 74.2; H, 4.78; N, 9.40.

Picrate.—Recrystallized from dilute alcohol as yellow needles; m. p. 115-116°.

Anal. Calcd. for $C_{15}H_{10}O_8N_4$: C, 48.13; H, 2.69; N, 14.97. Found: C, 48.1; H, 2.56; N, 14.8.

Summary

1. 2-Phenyloxazole and certain ortho-substituted derivatives have been prepared.

2. Preliminary pharmacological tests on 2-(osulfanilamidophenyl)-oxazole indicated antistreptococcal activity.

NEW YORK, N. Y. RECEIVED DECEMBER 29, 1941

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF PURDUE UNIVERSITY]

The Preparation and Isolation of 4-Methyl-1,3-pentadiene^{1,2}

By G. Bryant Bachman and Charles G. Goebel

The preparation of pure 4-methyl-1,3-pentadiene has occasioned considerable difficulty.³ Its formation by dehydration of the readily available 2-methyl-2,4-pentanediol is easily accomplished,

$$CH_{8} \xrightarrow{OH} O (CH_{2})_{2}C \xrightarrow{OH} CH_{2} + 2H_{2}O CH_{3} \xrightarrow{(CH_{3})_{2}C} CH_{2}CH_{2} + 2H_{2}O CH_{3} \xrightarrow{(CH_{3})_{2}C} CH_{2}CH_{2}CH_{2}CH_{2}CH_{3} + 2H_{2}O CH_{3} + 2H_{2}O CH_{3} \xrightarrow{(CH_{3})_{2}C} CH_{3} \xrightarrow{(CH_{3$$

but the principal product is the isomeric 2-methyl-1,3-pentadiene from which it cannot be separated satisfactorily by physical means.^{3c}

Turning to the chemical methods, we have found that reaction with maleic anhydride under controlled conditions effects a clean separation of the two isomers and permits the isolation of the desired diene. The 2-methyl derivative reacts under all conditions to

form an addition compound, 3,5-dimethyl-Δ⁴ (1) Presented before the Organic Division at the Atlantic City meeting of the American Chemical Society, September 8-12, 1941.

(2) From the M.S. dissertation of Charles G. Goebel.
(3) Cf. (a) Van Keersbilck, Bull. soc. chim. Belg., 38, 205 (1929);
(b) Krestinski, Ber., 55, 2760 (1922); (c) Kyriakides, THIS JOURNAL,
36, 994 (1914); (d) Diels and Alder, Ann., 470, 98 (1929); (e) Farmer, et al., J. Chem. Soc., 511 (1930); 3221 (1931); 1065 (1937);
(f) Whitby and Gallay, Can. J. Research, 6, 281 (1932); (g) Dupont and Darmon, Bull. soc. chim. Memoires, 6, 1208 (1939).

tetrahydrophthalic anhydride, and to some extent to form a polymer, but the 4-methyl compound forms only a polymer and no adduct.^{3e} In the presence of antipolymerization catalysts, at low

temperatures, and with a suitable choice of solvents, the polymerization reactions may be suppressed almost completely and pure 4-methyl-1,3-pentadiene isolated from the re-

action mixture.

Table I summarizes the results of these changes in conditions on the yields of polymer and adduct and on the molecular weight of the polymer. It



will be noted that the temperature exerts a far greater influence on the yield than does the nature of the solvent, except in the case of water, in which hydrolysis of the anhydride changes one of the reactants. The maximum yield of polymer (52.6%) and the maximum yield of adduct (77%)total more than 100\%, hence it is clear that under

P = poly Reaction 41 g. diene r	mer; $A = addimixture:mixture +$	uct. Numbers in	parenthese	s represent appro	ximate mol	ecular weights (\times	10 ⁻³).	
49 g. maleic anhydride + 125 g. solvent + - 0.05 g. added substance -			% Yields and molecular weights (X 10 ⁻³) Substance added					
		Nothing	Nothing		Hydroquinone		Benzoyl peroxide	
Solvent	Temp., °C.	Р	А	P	A	P	A	
None	4	46.5 (103)	51.6	1.1	75.5	52.6(24.8)	47.4	
Toluene	4	1.5 (8.8)	75.0	1.5	76.0	1.5	73.8	
	117	38.7 (10.2)	60.1	39.2 (9.4)	60.1	40.2 (9.9)	59.3	
Dioxane	4	1.5	77.0	0	77.0	3.4 (9.2)	73.0	
	111	40.4 (11.9)	58.0	2.5(8.7)	73.0	51.5 (9.4)	44.5	
Water	76	No reaction						

TABLE I DIENE-MALEIC ANHYDRIDR REACTION PRODUCTS

certain conditions some of the 2-methyl diene can polymerize rather than form an adduct. That none of the 4-methyl diene forms an adduct is shown by the fact that the adduct obtained from the reaction always melts sharply at the correct temperature for 3,5-dimethyl- Δ^4 -tetrahydrophthalic acid without further purification. As is to be expected, benzoyl peroxide promotes and hydroquinone inhibits the polymerization. By operating in dioxane cooled by an ice-water-bath, and in the presence of hydroquinone, adduct formation becomes complete and polymer formation nil. The diene isolated in 23% yield from a large scale run under these conditions was probably quite pure. It was tested for chemical homogeneity by reaction with maleic anhydride and gave a 96% yield of polymer containing no detectable amount of adduct. Oxidation with permanganate gave acetone and formic acid in copious quantities but no acetic acid.

$$(CH_3)_2C = CH - CH = CH_2 \xrightarrow{[O]} (CH_3)_2CO + HO_2C - CO_2H + HCO_2H \\ \downarrow \\ H_2O + 2CO_2$$

Finally distillation through a 20-plate column showed that the product boiled over a degree and a half range with 90% boiling at 76.3° (760 mm.). The density and refractive index were carefully determined and are compared in Table II with the constants selected by Egloff⁴ from earlier publications.

TABLE II									
PROPERTIES OF 4-METHYL-1,3-PENTADIENE									
	Pure diene	Egloff	Diene mixture						
Boiling point, °C.	76.3 (760)	76 (760)	75-77 (760)						
Density	0.7189204	0.7189^{20_4}	0.7114^{25}_{4}						
Ref. index, n²ºD	1.4505	1.4503	1.4473						

The reason for the difference in behavior be-

(4) Egloff, "Physical Constants of Hydrocarbons," Reinhold Publishing Corporation, New York, N. Y., 1939, Vol. I, p. 310. tween 2- and 4-methyl-1,3-pentadienes toward maleic anhydride constitutes an interesting question. It is probable that the concentration of methyl groups on the 4-methyl compound so lowers the reactivity of the double bond that it is no longer able to enter into the diene synthesis. If this is true, and the double bond in the 1 position is also the only one which polymerizes, the polymer should possess the structure



On the other hand, if the diene behaves like a typical diene both double bonds should react and the polymer should have the structure

$$\begin{bmatrix} -CH - CH - C(CH_3)_2 - CH = CH - CH_2 - \\ 0 \\ 0 \end{bmatrix}_n$$

The question was easily settled by an oxidation experiment. Treatment of a polymer obtained from a pure sample of the 4-methyl diene with permanganate gave a product whose viscosity was nearly the same as that of the original polymer. Oxidation definitely occurred as evidenced by the copious amounts of manganese dioxide formed, and yet multiple cleavage of the polymer chain could not have taken place without a very great change in viscosity. We conclude therefore that the polymer has the structure III and that only one double bond in the diene molecule is active toward maleic anhydride. We hope in the future to study other reactions of this unusual diene, especially some of the more common addition reactions. The substance is now readily available through the method of isolation developed in this work, and it will be interesting to determine how greatly the reactivities of the two double bonds differ.

A few heteropolymerization experiments were carried out with the original diene mixture using benzoyl peroxide as a catalyst. Polymers having molecular weights of about 9000 were obtained with maleic anhydride and styrene and maleic anhydride and vinyl acetate. Appreciable but undetermined amounts of adduct were present in these polymers. On the other hand, no polymers were obtained with the diene, and diethyl fumarate or diethyl maleate. Furthermore, in the absence of maleic anhydride the diene mixture did not polymerize readily with either styrene or vinyl acetate. Heated alone with benzoyl peroxide a mixture of polymers as described by Whitby and Gallay³⁴ was obtained.

The authors wish to express their appreciation for the generous amounts of the diene mixture supplied for this work by the Commercial Solvents Corporation.

Experimental

The Diene Mixture.—The mixture of dienes employed in this work was prepared in the research laboratories of the Commercial Solvents Company by distilling 2-methyl-2,4pentanediol with a little hydrobromic acid. The product as we received it was first distilled through a 20-plate Lecky column⁵ to remove any unchanged diol and other impurities present. The fraction of b. p. 75-77° was collected and stored in a brown glass bottle in the dark. It was a water-white liquid of pleasant odor and added bromine instantly.

The Isolation of 4-Methyl-1,3-pentadiene.--The following procedure is representative, except in the use of larger amounts, of the standardized procedure used to study the effects of variations in temperature, solvents, and catalysts (see Table I). To an ice-cold mixture of 0.5 g. of hydroquinone, 392 g. of maleic anhydride, and 1 liter of dioxane was added 328 g. of diene mixture, with frequent shaking and over a two-hour period. After standing in an ice box for three days, the dioxane and unreacted diene were removed by steam distillation. The upper layer of distillate was washed, dried, and fractionated through a 20-plate Lecky column. The fraction boiling at 75.5-77.0° was collected; yield, 76 g. (23% of the rectified diene mixture). On redistillation 90% boiled constantly at 76.3° (760 mm.). From the residue of the steam distillation was recovered 570 g. (72% yield) of 3,5-dimethyl- Δ^4 -tetrahydrophthalic acid, m. p. 154°. The anhydride, m. p. 57°, was obtained by heating above the melting point until dehydrated and recrystallizing from petroleum ether.

The homogeneity of the isolated 4-methyl-1,3-pentadiene was shown as follows: a mixture of 4.9 g. of maleic anhydride, 4.1 g. of diene and 20 g. of toluene was refluxed for one hour, cooled, and poured into petroleum ether. The insoluble, gummy polymer after thorough washing with fresh petroleum ether weighed 8.62 g. (96%). The solvent on evaporation yielded only a small amount of maleic an-

(5) Lecky and Ewell, Ind. Eng. Chem., Anal. Ed., 12, 544 (1940).

hydride, identified by its melting point (55°) and its mixed melting point with an authentic sample.

Oxidation of 4-Methyl-1,3-pentadiene.—A mixture of 5 g. of diene, 50 g. of potassium permanganate, 600 ml. of water and 1 kg. of ice, shaken frequently until the ice had melted, stood overnight. The solution, decolorized with manganous sulfate and neutralized with sodium carbonate, was distilled and the first 50 ml. of distillate tested with 2,4-dinitrophenylhydrazine. The recrystallized orange precipitate melted at 126° both alone and when mixed with an authentic sample of acetone 2,4-dinitrophenylhydrazone. After filtration and continued distillation nearly to dryness, the residual salts were acidified with dilute sulfuric acid and the distillation resumed. The distillate rapidly reduced aqueous silver nitrate to metallic silver, indicating formic acid. The filtrate from this reaction was evaporated to 10 ml. and cooled. No crystals of silver acetate appeared.

Oxidation of the 4-Methyl-1,3-pentadiene-Maleic Anhydride Heteropolymer.—Four grams of the polymer in 300 ml. of dioxane was oxidized as above with 40 g. of potassium permanganate. Large quantities of manganese dioxide separated, showing that oxidation had occurred. A solution of 1 g. of the recovered polymer in 25 g. of dioxane showed a specific viscosity of 0.850, while that for a similar solution of the original polymer was 0.875. These figures indicate that no appreciable degradation of the polymer chains occurred on oxidation.

Heteropolymerizations .- The polymerization of the diene mixture (1 mole) with maleic anhydride (2 moles) and either styrene (1 mole) or vinyl acetate (1 mole) in the presence of benzoyl peroxide (0.05%) took place readily at ice-bath temperatures with the evolution of much heat. The product in the case of styrene was an amber colored, brittle material, which was soluble in acetone and dioxane, soluble in warm benzene and toluene, and insoluble in carbon tetrachloride, chloroform, alcohol and petroleum ether. During the steam distillation to remove the adduct, which was present in appreciable amounts, the product showed no tendency to soften. The product in the case of vinyl acetate was a white, brittle solid. Steam distillation again showed the presence of an appreciable amount of the adduct. The product just softened in boiling water, and showed similar solubilities to those of the styrene heteropolymer.

Unsuccessful polymerizations which were attempted include the following: (a) diene mixture (1 mole), styrene (1 mole), benzoyl peroxide (0.05%), refluxed two hours; (b) same as (a) with vinyl acetate instead of styrene; (c) purified 4-methyl-1,3-pentadiene (1 mole), diethyl maleate (1 mole), benzoyl peroxide (0.05%), refluxed two hours; (d) same as (c) with diethyl fumarate instead of diethyl maleate.

Polymerization of the diene mixture alone using benzoyl peroxide (0.05%) as catalyst and refluxing for six hours gave a viscous solution with a reddish brown color. After removal of unchanged monomer and cooling, the product was a gray, sticky, rubber-like solid with red streaks in it. According to Whitby and Gallay³⁶ the gray substance is formed by the polymerization of the 2-methyl diene and the red substance by the dimerization of the 4-methyl diene. The red substance was more readily soluble in acetone than the gray

Molecular Weights of the Polymers.—Approximate values of the molecular weights were obtained with the aid of the Staudinger equation⁶ where η_{sp} is the specific viscos-

$$\eta_{\rm sp}/C = K_{\rm m}M$$

ity, C is the concentration of the polymer unit in moles per liter, M is the molecular weight of the polymer, and K_m is a constant characteristic of each type of polymer. Since the correct values for K_m were unknown an average value of 2×10^{-4} was taken. This value unquestionably introduces an error into the calculations, but it probably leads to a molecular weight of the right order of magnitude. The viscosities were measured with a Fenske–Ostwald pipet in a constant temperature bath on 4% solutions of the polymers in dioxane. The results are included in Table I.

(6) Staudinger, "Die hochmolekularen organischen Verbindungen," Verlag Julius Springer, Berlin, 1932.

Summary

A study has been made of the effects of solvents, temperature and catalysts on the reaction between maleic anhydride and the diene mixture resulting from the dehydration of 4-methyl-2,4pentanediol. By a suitable choice of conditions it has been found possible to leave the 4-methyl-1,3pentadiene in this mixture unreacted and to isolate it in a pure form in 23% yields. The boiling point, density and refractive index of this otherwise difficultly obtainable diene have been carefully determined.

LAFAYETTE, INDIANA RECEIVED NOVEMBER 14, 1941

[CONTRIBUTED FROM THE CHEMICAL AND OCEANOGRAPHIC LABORATORIES OF THE UNIVERSITY OF WASHINGTON]

Electrolytic Reduction of Strychnine

By Benj. M. G. Zwicker¹ and Rex J. Robinson

Under certain conditions strychnine has been reduced to form a series of di-acidic alkaloids which are extremely sensitive to oxidizing action in acid solution. The dyes resulting from their oxidation have been made the basis of a sensitive colorimetric test for nitrates. Harvey's² "Reduced Strychnine Reagent" is a mixture of these alkaloids prepared by zinc amalgam reduction of strychnine in dilute hydrochloric acid. The following work resulted from efforts to prepare the major components in Harvey's reagent in a more efficient manner with a view to studying their use as analytical reagents for nitrate.

While the double bond in the ether ring of strychnine has been catalytically reduced,³ the diacidic alkaloids resulting from reduction of the carbonyl group of the lactam⁴ ring are the ones which display the desired color reactions with dilute oxidants. Tetrahydrostrychnine and strychnidine have been obtained in about equal quantities from the electrolytic reduction of strychnine

$$\begin{array}{ccc} (C_{21}H_{22}ON) & & & \\ & & \\ & & \\ & & \\ Strychnine & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & & \\ & &$$

Strychnidine

(4) J. Tafel, Ann., 268, 229-55 (1892).

in 60% sulfuric acid by Tafel.⁵ Gentle oxidation of these compounds and their simple derivatives yields intense red dyes which Wieland and his coworkers⁶ concluded were meri-quinoid compounds formed by two molecules of the original base coupling in the position para to the indole nitrogen.

Difficulty was experienced in obtaining practical yields of the reduction products by the procedure of either Tafel or Perkin.⁷ This was attributed to the rapid insulation of the lead cathode by a coating of strychnine acid sulfate. Various modifications of these procedures did not materially improve the reaction rate. Lead dioxide, copper, tantalum and platinum cathodes also were tried but gave even lower yields than with lead.

However, the use of a mercury cathode increased the reaction rate as much as 800% compared to a lead cathode. Moreover, by proper regulation of temperature and reaction time it was possible to convert the strychnine mostly to tetrahydrostrychnine or strychnidine as desired. The use of a sodium amalgam cathode gave an even higher reaction rate but simultaneously reduced the double bond by as much as 30%.

The reaction rates were studied under various conditions of temperature, voltage and current

(5) J. Tafel, Ann., 301, 285-348 (1898).

Present address: The B. F. Goodrich Company, Akron, Ohio.
 H. W. Harvey, Conseil Permanent International L'exploration de la Mer, Rapport et Proces-Verbaux, 53, 68-74 (1929).

⁽³⁾ A. Skita aud H. H. Franck, Ber., 44, 2862-7 (1911).

⁽⁶⁾ H. Wieland, F. Calvet and W. W. Moyer, *ibid.*, **491**, 107–116 (1931).

⁽⁷⁾ G. R. Clemo, Wm. H. Perkin, Jr., and R. Robinson, J. Chem. Soc., 1589-1627 (1927).