m.p. 234–236°, no depression with yohimbine, $[\alpha]^{22}D + 47 \pm 4°$ (*c* 1.26 in ethanol), $[\alpha]^{22}D +76 \pm 4°$ (*c* 1.13 in pyridine). *Anal.* Calcd. for $C_{21}H_{26}N_2O_3$: C, 71.17; H, 7.40; N, 7.91; OCH_3, 8.75. Found: C, 70.92; H, 7.58; N, 7.92; OCH_3, 8.37.

Infrared spectra (Nujol) of both the alkaloid isolated by chromatography and the alkaloid isolated by fractional crystallization were identical with the spectrum of yohimbine.

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Formation Constants of Metal Complexes of Tropolone and its Derivatives. II. Some Alkyltropolones[1,2]

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The investigation of metal complexes of tropolone[4] has been extended to include the dissociation constants of methyl- and isopropyltropolones and the formation constants of some complexes of these substances with divalent metal ions.

Experimental

This investigation would not have been possible without the kindness of others in supplying samples of most of the substituted tropolones. To Professor T. Nozoe of Tohoku University, Sendai, Japan, we are indebted for the α-isopropyltropolone (m.p. 33–34°), β-isopropyltropolone (m.p. 52°), and for samples of α- and β-methyltropolone; to Professor A. B. Anderson of the University of California for γ-isopropyltropolone (m.p. 78–79°); and to Professor H. Erdtmann of The Royal Institute of Technology, Stockholm, Sweden, for β-isopropyl-γ-(3-methylbut-2-enyl)-tropolone.

Ring Expansion of 4-Methylcyclohexanone.—Five hundred grams of 4-methylcyclohexanone was allowed to react with diazomethane by the same procedure used by Kohler, Tishler, Potter and Thomson[5] to prepare cycloheptanone from cyclohexanone. Fractionation of the reaction mixture yielded 375 g. (67%) of 4-methylcycloheptanone, $n^{20}D$ 1.4590, distilling at 78° (16 mm.), and 110 g. of unreacted 4-methylcyclohexanone.

Oxidation of 4-Methylcycloheptanone.—A solution of 378 g. (3 moles) of 4-methylcycloheptanone in 700 ml. of absolute ethanol was brought to reflux in a 5-liter flask equipped with a reflux condenser, an efficient stirrer, and a dropping funnel. Over a period of 1.25 hr., a solution of 333 g. (3 moles) SeO_2 in 500 ml. of absolute ethanol and 1600 ml. of 95% ethanol was added *via* the dropping funnel. The solution was refluxed an additional 6 hr., and allowed to stand at room temperature for 18 hr. The precipitated selenium was filtered, and the filtrate boiled with Norit. About 1 liter of ethanol was distilled at atmospheric pressure, and the solution again filtered. Distillation was continued under vacuum. There was obtained 145 g. (55%) of a viscous, yellow material, boiling 79–103° (3 mm.).

Bromination of Diketone.—A solution of 140 g. (1.64 moles) of the diketones in 200 ml. of glacial acetic acid was cooled to 0°, and 520 g. (3.25 moles) of bromine in 200 ml. of glacial acetic acid was added to the cold, stirred solution over a period of 1 hr. The dark orange solution was allowed to stand at room temperature for 16 hr. The solution was was then heated until evolution of HBr ceased (1.5 hr.), and the acetic acid solvent was removed by steam distillation. The dark, tarry residue was extracted with ether. The ethereal extract was filtered and shaken with 6 *N* NaOH. The bright yellow precipitate was filtered and recrystallized from water; yield, 60 g., darkening at 240°, completely melted at 265°.

Apparently some impurity in this material poisoned the palladium catalyst used in catalytic debromination, so the material was dissolved in water and the solution acidified with 2 *N* H_2SO_4. The acidified solution was extracted with ether, and the extract was shaken with 6 *N* NaOH. The butter-yellow precipitate was filtered, washed with cold brine and recrystallized from 95% ethanol. This material was found to darken at *ca.* 240° and melt at 250–260°.

Although a mixture of materials was expected, all attempts to separate the yellow material failed. Paper chromatograms, developed with $FeCl_3$, indicated that only one active compound was present.

β-Methyltropolone.—Five grams of the above material, 1 g. of 10% palladium-charcoal and 200 ml. of 95% ethanol were shaken under H_2 until uptake ceased (1.5 hr.). The ethanol was stripped under vacuum and the residue was extracted with ligroin. The extract yielded 1.6 g. of material, melting 60–63°. Repeated recrystallization yielded 1.3 g. of material, m.p. 69–70°. A sample of β-methyltropolone furnished by Professor T. Nozoe was found to melt 73–74°. A mixture of the two samples melted 69–70°. *Anal.* Calcd. C, 70.6; H, 5.88. Found: C, 70.0; H, 5.92.

2-Methylcycloheptanone.—From 129 g. of cyclohexanone, 40 g. (27.4%) of 2-methylcycloheptanone, b.p. 36° (2 mm.), $n^{20}D$ 1.4534, was prepared in a manner similar to that previously mentioned[5] by the generation *in situ* of diazoethane from nitrosoethylurethan. The low yield, compared to that reported for a different method[6] can be explained by the fact that the nitrosoethylurethan was used without purification.

3-Methylcycloheptane-1,2-dione.—In a manner analogous to the SeO_2 oxidation described above, 127 g. of 2-methylcycloheptanone yielded 30 g. (17.3%) of 3-methylcycloheptane-1,2-dione, b.p. 65° (3 mm.), $n^{20}D$ 1.4787.

α-Methylbromotropolone.—Thirty grams of the above diketone in 30 ml. of glacial acetic acid was cooled to 0°, and 78 g. of bromine in 30 ml. of glacial acetic acid was added to the cold, stirred solution dropwise over a period of 4 hr. The temperature was maintained at 0° throughout addition of bromine. The dark solution was allowed to stand for 16 hr. at room temperature. The major portion of the acetic acid was then removed under reduced pressure and the residue was steam distilled. The distillate deposited cream-colored needles which were separated, and the distillate was extracted with toluene. The toluene was evaporated and the residue was recrystallized from 95% ethanol; fine, cream-colored needles, m.p. 121°, yield 8 g. (17%).

α-Methyltropolone.—The bromo compound was dissolved in ether and shaken with 6 *N* NaOH to yield the **sodium salt of α-methylbromotropolone**, brilliant yellow powder, darkening at *ca.* 265°, completely black at 295° but failing to melt below 300°. Ten grams of the salt was dissolved in 270 ml. of 95% ethanol and 1 g. of 10% Pd–charcoal was added. The solution was shaken under H_2 until hydrogen absorption ceased. The catalyst was filtered and the alcohol was removed from the red solution at room temperature under reduced pressure. The residual red oil was extracted with ligroin. The extract deposited light cream-colored plates upon chilling in acetone–Dry Ice. The crystals were filtered and the same ligroin used for extraction until chilling failed to induce further crystallization. Repeated recrystallization from ligroin yielded 3.0 g. (59%) of cream-colored plates, m.p. 48–50°. An authentic sample, supplied by T. Nozoe melted 49–51°. A mixture of the samples melted 48–50°.

Titrations were performed as described previously[4] with the exception that it was generally found necessary to evaluate the first formation constants of the Be, Pb and Zn complexes by a modified procedure. In the presence of excess chelating agents it was found that coördination was so far

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(1) Taken in part from a dissertation presented by Burl E. Bryant in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1952.

(2) Presented in part before the Fifth Annual Meeting-in-miniature of the Philadelphia Section of The American Chemical Society, January 29, 1953.

(3) Public Health Service Research Fellow of the National Institutes of Health, 1953–1954.

(4) B. E. Bryant, W. C. Fernelius and B. E. Douglas, THIS JOURNAL, **75**, 3784 (1953).

(5) E. P. Kohler, M. Tishler, H. Potter and H. T. Thomson, *ibid.*, **61**, 1057 (1939).

(6) A. P. Giraitis and J. L. Bullock, *ibid.*, **59**, 951 (1937).

TABLE I

Compound	pK_D	n	log K_{fn} Be^{++}	Pb^{++}	Zn^{++}	Ni^{++}	Co^{++}	Mg^{++}	Ca^{++}
α-Methyltropolone	9.37	1	10.3	9.4	8.6	8.4	8.0	6.0	5.1
		2	9.0	6.7	7.1	6.7	6.3	4.6	3.4
		3				3.7		2.6	
β-Methyltropolone	8.69	1	9.4	9.6	8.4	8.4	7.9	6.0	5.3
		2	7.7	6.6	6.8	6.6	6.2	4.6	3.6
		3			3.6	4.1		3.1	
α-Isopropyltropolone	9.75	1	10.7	9.5	8.7	8.6	8.1	6.2	5.2
		2	9.1	7.5	7.5	6.9	6.7	5.2	3.6
		3				3.7			
β-Isopropyltropolone	8.70	1	9.1	9.0	8.7	8.5	7.9	6.2	5.4
		2	7.5	6.7	7.0	6.5	6.3	4.8	3.6
		3			3.6	4.0	3.8	3.0	
α-Isopropyltropolone	8.7	1				8.4			
		2				6.5			
		3				3.9			
Tropolone	8.12	1	8.4			7.7			
		2	7.0			6.1			
Acetylacetone	9.70	1	9.0			6.9			
		2	7.7			5.1			

advanced that $\bar{n}$ was equal to one or greater before the addition of base. To obtain values in the region of $\bar{n}_q = 0.5$, solutions containing two moles of metal ion per mole of chelating agent were titrated. In these cases, constants were not calculated from formation curves, but by the method of Block and McIntyre.[7]

Attempts to titrate an excess of α-isopropyltropolone in the presence of Be ion led to the precipitation of yellow plates, m.p. 177°. *Anal.* Calcd. for $Be(C_{10}H_{11}O_2)_2$: C, 71.64; H, 6.57. Found: C, 71.36; H, 6.34.

Addition of a solution of $Pb(NO_3)_2$ to α-isopropyltropolone in 50% dioxane caused precipitation of light yellow plates, m.p. 164°. *Anal.* Calcd. for $Pb(C_{10}H_{11}O_2)_2$: C, 45.03; H, 4.13. Found: C, 45.44; H, 4.12.

The Ni and Be complexes of β-isopropyl-γ-(3-methylbut-2-enyl)-tropolone were found to be too insoluble for study by this method.

Discussion

The values determined are shown in Table I. In a previous publication,[4] it was pointed out that the copper tropolonate was more stable than copper derivatives of β-diketones of comparable acidity. Included in Table I are the values of the Be and Ni derivatives of acetylacetone. If the values of the first or second formation constants of the Ni or Be complexes are plotted *vs.* the pK_D values of the respective chelating agents it is found that the complexes of tropolone and its derivatives group themselves about a single straight line, while the acetylacetone derivative of the metal ion in question is considerably (*ca.* 1.5 log units) removed from the line for the tropolone derivatives. Again it is seen that the tropolone complexes are more stable than those of β-diketones of comparable acidity.

Calvin and Wilson[8] have postulated that resonance within the chelate ring may considerably enhance the stabilities of compounds such as these. The unusual nature of the plots of log K_f *vs.* pK_D for the tropolone complexes suggests several possibilities: 1. Resonance energy of the tropolone complexes is unusually high. 2. There is an unusually high contribution to stability due to the favorable size of the five-membered chelate ring. 3. Due to the unfavorable oxygen–oxygen distance in tropolone[9] the weak hydrogen bond causes tropolone to act as an unusually strong acid.

Professor M. Calvin[10] has suggested that the unusual character of these plots is best explained on the basis of the unusually high acidity of the tropolones rather than an unusual stability of these complexes. It is interesting to observe that the behaviors of the two smallest ions studied (H^+ and Be^{++}) are markedly similar; *i.e.*, the α-ions are bound more strongly than the β-substituted ions. For ions larger than Be^{++}, however, only minor differences are noted between the α- and β-compounds.

The effects of hydrogen bonding and the size of the chelate ring on the nature of plots of log K_f *vs.* pK_D are being investigated further.

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Extensions of the Tollens Condensation

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The hydroxymethylation and subsequent reduction of carbonyl compounds containing active hydrogen atoms by means of formaldehyde and calcium or sodium hydroxide[1] has been applied to some monosubstituted acetaldehydes, YCH_2CHO, to

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[7] B. P. Block and G. H. McIntyre, Jr., THIS JOURNAL, **75**, 5667 (1953).

[8] M. Calvin and K. Wilson, *ibid.*, **67**, 2003 (1945).

[9] J. M. Robertson, *J. Chem. Soc.*, 1222 (1951).

[10] M. Calvin, private communication.

[1] B. Tollens and P. Wiegand, *Ann.*, **265**, 316 (1891).