

traces of styrene present initially and from progressive oxidation during reaction.

This mechanism clearly explains why disproportionation of ethylbenzene is so much more rapid than toluene.<sup>3</sup> The recent isolation of 1-(ethylphenyl)-1-phenylethanes from the treatment of ethylbenzene with ferric chloride<sup>6</sup> also may be pertinent. The mechanism previously has been postulated to account for some disproportionation results in the presence of fairly high concentrations of hydrogen acceptors.<sup>7</sup> The present results show that the mechanism can be operative under normal transalkylation or disproportionation conditions and may be general for primary alkylbenzenes; there seems little question that transalkylation of secondary and tertiary alkyl groups generally involves essentially free alkyl cations.

A number of obvious corollaries of the new mechanism have not yet been studied. The present results compel that the new mechanism be given serious consideration in other disproportionation and transalkylation studies.

(6) P. Kovacic, C. Wu and R. W. Stewart, *THIS JOURNAL*, **82**, 1917 (1960).

(7) H. Pines and J. T. Arrigo, *ibid.*, **80**, 4369 (1958); L. Schmerling, J. P. Luvisi and R. W. Welch, *ibid.*, **81**, 2718 (1959).

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#### ELECTRONIC STRUCTURE AND MOLECULAR ASSOCIATION OF SOME BIS-( $\beta$ -DIKETONE)-NICKEL(II) COMPLEXES

Sir:

Recently<sup>1,2</sup> it was shown from ligand field arguments that one may expect planar, tetracoördinate complexes of Ni(II) to be either paramagnetic or diamagnetic depending on the strength of the surrounding field. Bis-acetylacetonato-Ni(II) has been cited as a prominent example of a planar paramagnetic material. Studies in this laboratory make it increasingly apparent that the spin-free ground state may be caused by intermolecular associations, instead of being characteristic of the free monomeric molecule.

While bis-(acetylacetonato)-Ni(II), I, is planar<sup>3</sup> and monomeric<sup>4</sup> in the vapor phase, an incomplete

(1) G. Maki, *J. Chem. Phys.*, **28**, 651 (1958); **29**, 162 (1959); **29**, 1129 (1959).

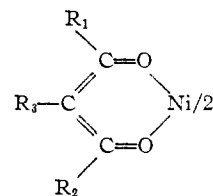
(2) A. H. Liehr and C. Ballhausen, *THIS JOURNAL*, **81**, 538 (1959).

(3) S. Shibata, *Bull. Chem. Soc. Japan*, **30**, 753 (1957).

(4) F. Gach, *Monatsh. Chemie*, **21**, 98 (1900).

X-ray analysis of the sublimed solid<sup>5</sup> indicates intermolecular associations. The material is known to form a dihydrate readily, suggesting a strong tendency for the Ni(II) to become octahedrally coordinated. While the visible spectrum and magnetic properties of the complex in hydrocarbon solvents exclude a tetrahedral arrangement, octahedral coordination by means of polymerization is not excluded. Molecular weight determinations in dichloromethane indicate that I is substantially polymerized.<sup>6</sup> The preparation and characterization of the complexes reported offers additional evidence for this view.

Bis-(2,2,6,6-tetramethyl-3,5-heptanediono)-Ni(II), II, ( $R_1 = R_2 = -C(CH_3)_3$ ,  $R_3 = H$ ) was found



to be diamagnetic. Hydrocarbon solutions of the material exhibit a single absorption peak in the visible at 535 m $\mu$ , with a molar extinction coefficient of 60, giving a red coloration. The material readily forms a blue-green paramagnetic dihydrate.

*Anal.* Calcd. for  $NiC_{22}H_{38}O_4$ : C, 62.14; H, 8.92. Found: C, 61.98; H, 8.92.

Bis-(2,2-dimethyl-3,5-heptanediono)-Ni(II), III ( $R_1 = R_2 = -CH(CH_3)_2$ ,  $R_3 = H$ ), was found to be paramagnetic,  $\mu_{eff}$  (297.4° K.) = 3.41 B.M., in the solid phase. Toluene solutions of the anhydrous material indicate that the magnetic moments of the solutions are concentration and temperature dependent. The color of the solutions changes from green near 0° to red at around 50°, corresponding to the growth of a band at 535 m $\mu$ . All attempts to explain the magnetic properties of these solutions and the growth of the 535 m $\mu$  band by means of a Boltzmann distribution of the molecules in the singlet and triplet states<sup>2</sup> failed. The concentration dependence of both the moment and the intensity of the 535 m $\mu$  band excluded this assumption and led to an attempt to correlate the data assuming a temperature-dependent distribution among monomers and polymers in solution. Assuming the monomer to be diamagnetic and to be the only species absorbing at 535 m $\mu$ , it was possible to fit the data at several concentrations and temperatures to a set of equilibrium expressions.

*Anal.* Calcd. for  $NiC_{18}H_{30}O_4$ : C, 58.57; H, 8.11. Found: C, 58.48; H, 8.29.

The spin-paired ground state in II can be attributed to the fact that the bulky *t*-butyl groups prevent intermolecular association. Scale molecular models indicate that only slight strain is in-

(5) G. J. Bullen, *Nature*, **177**, 537 (1956). Drs. R. Mason and P. Pauling at University College London recently have re-examined Bullen's three-dimensional data and find that the molecules in the trimer are so arranged that each nickel ion is surrounded by six oxygen atoms in a slightly distorted octahedron (private communication).

(6) F. A. Cotton and R. H. Soderberg, to be published.

curred when the Ni(II) atom in III is placed near the oxygens or chelate ring of a neighboring molecule. The tendency for Ni(II) to become octahedrally coordinate apparently overcomes this strain in the solid.

Preliminary studies on a third compound, bis-(3-phenyl-2,4-pentanediono)-Ni(II), IV, ( $R_1 = R_2 = CH_3$ ,  $R_3 = C_6H_5$ ) gives additional support to the idea that the paramagnetism in anhydrous  $\beta$ -diketone complexes of Ni(II) can be attributed to intermolecular interactions. Models indicate that the phenyl group in IV cannot rotate into coplanarity with the chelate ring due to the proximity of the methyl groups. Close intermolecular association of the Ni(II) atom with a neighboring molecule would be hindered by the phenyl groups perpendicular to the chelate ring. The anhydrous material, from drying the blue-green hydrate, is red and diamagnetic, a single band being observed in the visible spectrum of the solid at 535  $m\mu$ . In toluene the material appears to behave similarly to III, the color of the solution changing from green to red as the temperature is increased from 0 to 50°. It also appears that a green crystalline modification of the material can be formed by melting the red powder.

Studies are also being carried out on the visible spectrum of I in hydrocarbon solutions at fairly high temperatures. It has been observed visually that the color of solutions of I in dibenzyl become reddish-brown near 200° and reversibly return to the green color upon cooling.

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#### COSYNTHESIS OF TETRACYCLINES BY PAIRS OF *STREPTOMYCES AUREOFACIENS* MUTANTS.

Sir:

In the course of our studies on the biosynthesis of the tetracyclines we have sought for and found numerous blocked mutant strains of *Streptomyces aureofaciens* Duggar which have lost their ability to elaborate any substantial quantity of tetracycline antibiotics. In order to determine whether such mutants might show biological cooperation in the synthesis of tetracycline antibiotics, they were then grown as pairs in mixed fermentation, and the resulting fermented mash examined for tetracyclines. Typical data summarized in Table I show that in many cases substantial quantities of one or more tetracyclines were produced in the mixed fermentations even when each mutant grown alone produced no appreciable amount. It should be noted that the methods used resulted in the selection of only those mutants which grew well in a corn steep medium<sup>1</sup> ordinarily used for

the elaboration of the tetracyclines. Therefore we have used the term cosynthesis for this phenomenon to distinguish it from the previously reported microbial systems involving cross-feeding of essential nutritional factors (syntrophism).<sup>2,3</sup>

TABLE I  
COSYNTHESIS OF TETRACYCLINE ANTIBIOTICS

| Mutants <sup>a</sup><br>grown<br>alone | Principal<br>tetracycline<br>product of<br>parent strain <sup>b</sup> | Tetracycline<br>product of<br>mutant <sup>b</sup> | Anti-<br>bacterial<br>assay <sup>c</sup> of<br>fermented<br>mash,<br>g./l.                     |
|--|---|---|--|
| S-1308                                 | 7-Cl-TC   | 7-Cl-TC plus<br>7-Cl-5a(11a)-<br>dehydro TC       | 0.20   |
| W-5                                    | 7-Cl-TC   | Unknown   | Nil  |
| E-504                                  | 7-Cl-6-demethyl-TC  | Unknown   | Nil  |
| T-219                                  | TC  | Unknown   | Nil  |
| S-2242                                 | 7-Cl-TC   | Unknown   | Nil  |
| Mutants<br>grown as<br>mixtures        | Tetracycline<br>products<br>cosynthesized <sup>b</sup>                |   | Anti-<br>bacterial<br>assay <sup>c</sup> of<br>mixed fer-<br>mentations, <sup>d</sup><br>g./l. |
| S-1308 + W-5                           | 7-Cl-TC   |   | 2.7  |
| W-5 + E-504                            | 7-Cl-6-demethyl-TC  |   | 0.22   |
| T-219 + S-2242                         | 7-Cl-TC plus TC   |   | 0.74   |
| S-1308 + E-504                         | None  |   | Nil  |
| E-504 + T-219                          | 7-Cl-TC plus 7-Cl-6-<br>demethyl-TC                                   |   | 0.34   |
| W-5 + S-2242                           | None  |   | Nil  |

<sup>a</sup> Some of these mutants were obtained through the courtesy of Dr. J. Growich of these laboratories. <sup>b</sup> TC = tetracycline. <sup>c</sup> *S. aureus* turbidimetric assay calculated as 7-chlorotetracycline. <sup>d</sup> Corrected for assay of mutants grown alone.

The mechanisms involved in cosynthesis are assumed to be analogous to those involved in syntrophism, that is, the transfer of biosynthetic intermediates from the mutant of the later block to the mutant of the earlier block or, alternatively, the transfer of the missing facility from either mutant to the other, resulting in the cooperative biosynthesis of the normal product of the parent strain.

We wish to report in greater detail the results of our study of one of these cosynthetic pairs. The two mutants used were coded W-5 and S-1308; both were isolated directly from high 7-chlorotetracycline-producing parent strains. Mutant W-5 was an unpigmented mutant lacking the ability to elaborate significant quantities of 7-chlorotetracycline and presumably blocked early in the biosynthetic pathway. The other mutant of this pair, S-1308, was pigmented; it produced 7-chloro-5a(11a)-dehydro-tetracycline<sup>4</sup> to the extent of about 4.0 g./l. together with about 0.2 g./l. of 7-chlorotetracycline. When 48 hour-old shaker flask cultures of W-5 and S-1308 were mixed in equal volume and incubated an additional 72 hours, 2.8 g./l. of 7-chlorotetracycline and correspondingly less of 7-chloro-5a(11a)-dehydro-tetracycline were produced.

(1) J. J. Goodman, M. Matrishin, R. W. Young and J. R. D. McCormick, *J. Bact.*, **78**, 492 (1959).

(2) J. Lederberg, *ibid.*, **52**, 503 (1946).

(3) B. D. Davis, *Experientia*, **6**, 41 (1950).

(4) J. R. D. McCormick, P. A. Miller, J. A. Growich, N. O. Sjolander and A. P. Doerschuk, *THIS JOURNAL*, **80**, 5572 (1958).