

show the points at which, on the average, distinct symptoms of polyneuritis developed. At the levels of vitamin B feeding represented by the higher curves, polyneuritis was prevented and the individual differences were not so great; but also there was a lessened response in growth to a given small increment of vitamin B intake, so that the method while gaining in accuracy was losing in delicacy.

A rate of gain of 3 g. per week affords such a combination of accuracy and delicacy as to be a good basis for quantitative comparisons, and it has the added advantage of being already familiar as the "standard" rate of gain in the analogous determinations of vitamin A values.

We therefore recommend that in order to facilitate quantitative comparisons: a "unit" of vitamin B be considered to be that amount which, when fed as a daily allowance to a standard test animal (rat), under such conditions as have been indicated above, will suffice to support three grams per week of gain in weight during an experimental period of not less than four nor more than eight weeks.

Separate summary and conclusions are here purposely omitted because this paper as a whole is an attempt at concise summary of experimental data too numerous to be printed in detail; and because, as already explained, each quantitative investigator must still establish experimentally his own conclusions as to certain points comprised within the general plan and principles outlined above.

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MIXED BENZOINS. VII. MAXIMAL CATALYTIC REDUCTION

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Several papers have been published on the catalytic reduction of benzoins and related compounds.^{1,2,3} While attempting to prepare certain reduction products of some benzoins the authors were unable to obtain end-points for the intermediate stages of reductions. It was therefore decided to reduce the benzoins to the maximum extent. Seven mixed benzoins and benzoins themselves were so reduced. From benzoin,³ *o*-chlorobenzoin⁴ and *o*-chlorobenzveratrin,⁴ α,β -dicyclohexylethane⁵ and

¹ Buck and Jenkins, *THIS JOURNAL*, 51, 2163 (1929).

² Jenkins, Buck and Bigelow, *ibid.*, 52, 4495 (1930).

³ Kariyone, *J. Pharm. Soc. Japan*, No. 515, 1 (1925).

⁴ Buck and Ide, *THIS JOURNAL*, 52, 4107 (1930).

⁵ Obtained in other ways by Freundler, *Compt. rend.*, 142, 343 (1906); *Bull. soc. chim.*, [3] 35, 541, 549 (1906); Sabatier and Murat, *Compt. rend.*, 154, 1771 (1912).

a compound melting at 194°, most probably α,β -dicyclohexylethylene glycol, were obtained, the latter being the chief product at room temperature, the former at higher temperatures. No methoxy compounds were isolated and, although not completely excluded, their presence is improbable. Evidently, under the conditions employed, both methoxyl and chlorine groups are stripped from the rings at some stage of the reduction and the rings are finally completely reduced.

A number of benzoins containing the dimethylamino group were also reduced. From *p*-dimethylaminobenzoin,⁴ *p*-dimethylaminobenzoin,⁶ and ortho-,⁷ meta-⁴ and para-chlorodimethylaminobenzoin^{6,8} the same product, 4-dimethylamino- α,β -dicyclohexylethane was obtained in fair yield. The methoxyl and the *o*-, *m*- and *p*-chloro groups are all split off and the molecule completely reduced. Small amounts of other compounds were formed but in insufficient quantities to permit of examination.

It is not possible to fix precisely the mechanism of the reduction. One fact of significance is that for the reduction to proceed beyond the hydrobenzoin stage, free hydrochloric acid must be present. In the case of the chlorine compounds this is produced by the action of the hydrogen and the catalyst, the reaction mixture, originally neutral, becoming strongly acid. With the dimethylamino compounds acid was usually added at the start, for solubility reasons. The reduction is complex, and in the case of the dimethylamino compounds varying, but always considerable amounts of a clear, stiff gum were obtained together with a little non-basic material. The gum gave no crystalline derivatives and was possibly the same in all cases. With the other benzoins some non-volatile gum was also formed but in smaller amounts. The final products are evidently the result of a chain of alternate reductions and reactions involving elimination of water (the latter taking place under the influence of the acid as noted by Buck and Jenkins¹), during the course of which ample opportunity for polymerization and for side reactions occurs.

Experimental

Benzoins.—The benzoins were prepared as cited above. They must be very pure. Several recrystallizations from alcohol and finally from acetic acid are necessary.

Catalyst.—The catalyst used was platinum oxide prepared after the method of Adams. The source of platinum chloride is of importance, "Platinum Chloride, Crystal" of the J. T. Baker Co. giving the best results in the hands of the authors. The platinum was recovered by ashing the filter papers, etc., and fusing the ash with sodium nitrate, the metallic platinum so produced being then dissolved in aqua regia. Material recovered in this manner was superior in activity to the original catalyst.

⁴ Staudinger, *Ber.*, **46**, 3535 (1913).

⁷ Buck and Ide, *ibid.*, **52**, 220 (1930).

⁸ Since submitting this paper, Jenkins, *THIS JOURNAL*, **53**, 3115 (1931), has described some of the reduction products of this benzoin. They were obtained by purely chemical methods. Catalytic reduction is not mentioned.

Reduction.—A Burgess–Parr apparatus was used, fitted with an additional (micro) gage and an electric heater.¹ One-fiftieth mole of the benzoin (about 5 g.) was dissolved in 50 cc. of alcohol, or in the case of benzoin itself and the dimethylaminobenzoins, in 40 cc. of alcohol and 10 cc. of concd. hydrochloric acid. The reduction was carried out at about 70° and requires less than two hours. At lower temperatures reduction takes place very slowly, sometimes requiring days. In all cases 1.0 g. of platinum oxide was used as catalyst. The amount of hydrogen taken up varies with different runs, but is usually somewhat short of the theoretical amount (100% formation of the dicyclohexylethane derivative). Really accurate measurement was not possible with the apparatus used on account of the difficulty of closely controlling the temperature over a somewhat protracted run.

α,β -Dicyclohexylethane.—The solution, after the reduction of benzoin (hydrochloric acid present), *o*-chlorobenzoin or *o*-chlorobenzveratroin was concentrated, after filtering off the separated compound, m. p. 194°. A second crop crystallizes out and is filtered off. The liquors were then steam distilled, the distillate extracted with ether, and the oil remaining after the removal of the ether fractionated several times under reduced pressure, the last fractionations being over metallic sodium. Identity of specimens from different sources was established by boiling point, refractive index, properties and analysis.

The compound forms a slightly viscous, colorless oil with a faint odor reminiscent of octyl acetate. It is inert toward even powerful reagents, such as permanganate, chromic acid, cold nitric acid and sodium. No derivatives could be obtained. The data are similar to those given by Sabatier and Murat:⁵ b. p. 132° (8 mm.), d_{25}^{25} 0.8758, n_D^{25} 1.4749, M_D (n^2), calcd. 62.45; found, 62.42.

Anal. Calcd. for $C_{14}H_{26}$: C, 86.50; H, 13.50. Found: C, 86.24; H, 13.78.

Compound m. p. 194° (α,β -Dicyclohexylethylene Glycol?).—When *o*-chlorobenzoin and *o*-chlorobenzveratroin are reduced at ordinary temperatures, a considerable amount of a white, crystalline compound separates out. The same compound is obtained by reducing benzoin at about 70° in the presence of hydrochloric acid. It is also present in varying amounts in the residues from the steam distillations. After purification by recrystallization from alcohol, it forms white, glittering, flat, slender rectangular prisms, melting at 193–194° and remelting at about 200°. It is moderately soluble in hot alcohol, somewhat soluble in warm ether, and soluble in warm acetic acid. With cold, concd. sulfuric acid it gives a colorless solution. The compound is very stable, sublimes when heated, cannot be reduced catalytically, is unaffected by boiling hydrochloric acid, shows no carbonyl reactions and forms a monoacetyl derivative.

Anal. Calcd. for $C_{14}H_{26}O_2$: C, 74.34; H, 11.59; mol. wt., 224. Found: C, 75.05; H, 11.73; mol. wt. (Rast), 223.

The above analysis represents the mean of a number of concordant analyses on different samples. The high carbon value, which was constantly found, cannot be explained. For this reason, together with the rather high melting point and the stability of the compound, the authors regard the identification as α,β -dicyclohexylethylene glycol as being provisional only. As a matter of fact it was for some time believed to be the *meta*-hexahydrobenzaldehyde of Wallach,⁹ but, although very similar to this, direct comparison showed it to be not identical.

The acetyl compound, formed by heating with acetic anhydride on the water-bath, forms a chalky mass of tiny needles when recrystallized from aqueous alcohol. The melting point is 133°.

Anal. Calcd. for $C_{16}H_{28}O_3$: C, 71.58; H, 10.52. Found: C, 71.46; H, 10.87.

⁹ Wallach, *Ann.*, **347**, 316 (1906).

4-Dimethylamino- α,β -dicyclohexylethane.—The solutions from the reduction of *p*-dimethylaminobenzoin, *p*-dimethylaminobenzanisoin, or *o*-, *m*- and *p*-chlorodimethylaminobenzoin were diluted, made alkaline with potassium hydroxide and extracted with ether. After removing the ether, the viscous oil remaining was steam distilled for a short time to remove volatile impurities and the residue extracted with ether (some solid usually separated at this point), the ether evaporated and the oil fractionated under low pressure until pure. Alternatively, the compound may be obtained pure by regeneration from the picrate. The products from different preparations were identified by properties, analysis, refractive index, boiling-point and mixed melting-point determinations of the picrate.

4-Dimethylamino- α,β -dicyclohexylethane forms a colorless, slightly viscous liquid with a faint odor of onions: b. p. 170° (9 mm.), 132° (0.7 mm.), d_{25}^{25} 0.9054, n_D^{25} 1.4845; M_D (n^2) calcd., 75.62; found, 75.11.

Anal. Calcd. for $C_{16}H_{21}N$: C, 80.93; H, 13.17; N, 5.90. Found: C, 80.84; H, 13.12; N, 6.29.

The picrate was prepared in alcoholic solution and recrystallized from alcohol. It forms bright yellow, glittering crystals, melting at 148–150°. It is slightly soluble in hot water, readily soluble in hot alcohol and fairly soluble in cold acetic acid.

Anal. Calcd. for $C_{16}H_{21}N \cdot C_6H_5O_7N_3$: C, 56.62; H, 7.35. Found: C, 56.65; H, 7.32.

With the non-nitrogenous benzoins, α,β -dicyclohexylethane and the compound m. p. 194° account for nearly all the starting material. With the dimethylaminobenzoins, 25 to 50% is accounted for as 4-dimethylamino- α,β -dicyclohexylethane, the rest being uncrystallizable and non-volatile material. Several other benzoins were investigated, but under the conditions employed they failed to reduce beyond the hydrobenzoin stage. They were anisoin, benzanisoin, piperoin and *o*-chlorobenzpiperoin.

Summary

Benzoin, *o*-chlorobenzanisoin and *o*-chlorobenzveratroin have been catalytically reduced to α,β -dicyclohexylethane and a compound melting at 194°, most probably α,β -dicyclohexylethylene glycol.

p-Dimethylaminobenzoin, *p*-dimethylaminobenzanisoin, and *o*-, *m*- and *p*-chlorodimethylaminobenzoin are all reduced to 4-dimethylamino- α,β -dicyclohexylethane.

All substituents except the dimethylamino group are lost during the reduction.

The reductions were all carried out with platinum oxide and hydrogen at about 70°.

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