

The Course of Hydrogenation of Nickel(II) β -Alkylated 1,19-Dimethyl-tetradehydrocorrin Salts

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The course of hydrogenation of nickel and cobalt tetradehydrocorrin salts is profoundly affected by the β -alkyl substitution pattern. In the absence of alkyl substituents at C-2 and C-18, the hydrogenation products vary according to the experimental conditions. At room temperature, rings A and D are hydrogenated with the formation of the nickel BC-didehydrocorrin salt whereas at 100° the isomeric nickel AD-didehydrocorrin salt is obtained. Further hydrogenation of these products yields the amorphous nickel corrin salts often accompanied by the corresponding 4,5-dihydrocorrin salts. Vigorous hydrogenation of nickel(II) tetradehydrocorrin salts bearing alkyl groups at positions 1, 2, 18, and 19 can yield either an isocorrin salt or its 17,18-dehydro-derivative and their formation is a consequence of the steric crowding of the alkyl substituents around the direct AD linkage. Easy dehydrogenation at certain specified positions in the hydrogenated nickel salts has been observed in the mass spectrometer and the results have been correlated with the postulated structures.

In a previous paper,¹ we have described the hydrogenation of nickel(II) and cobalt(II) β -unsubstituted, 1,19-dimethyltetradehydrocorrin salts (I; $R^1 = R^2 = R^3 = R^4 = H$) to the corresponding metal corrin salts (II) and 4,5-dihydrocorrin salts (III), both of which were isolated as the crystalline perchlorates. In another paper,² we had reported other examples of this type of synthesis of nickel and cobalt corrin salts where β -alkyl substituents, other than at C-2 and C-18, were present. These β -alkylated corrin salts were not obtained as crystalline products, possibly because of the number of isomeric forms which were produced. We now describe extensions of the studies of the course of the stepwise hydrogenations of the nickel(II) and cobalt(II) 1,19-dimethyl-tetradehydrocorrin salts and present further examples

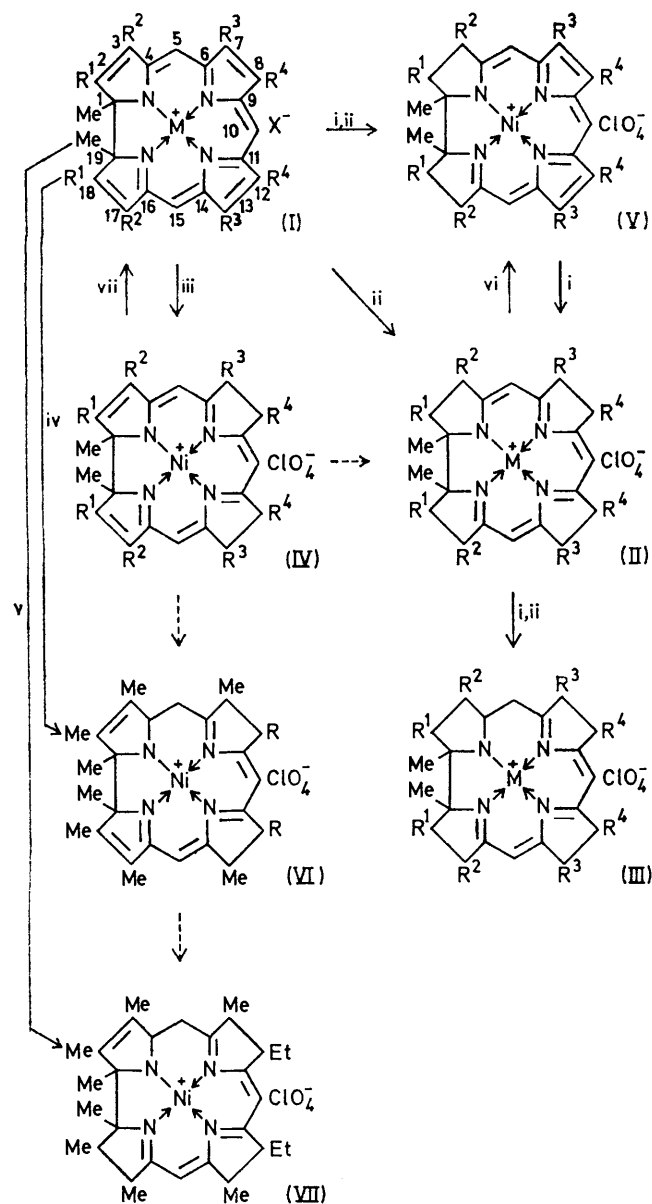
¹ A. W. Johnson and W. R. Overend, *J.C.S. Perkin I*, 1972, 2681.

of the profound effect in this series of the C-2 and C-18 alkyl substituents on the course of the reaction, as well as of effects of other β -alkyl substituents. The overall picture of the hydrogenation reactions is summarised in the Scheme.

Nickel AD- and BC-Didehydrocorrin Salts (Hexa-, Octa-, and Deca-alkyl Series).—Hydrogenation of both nickel 1,3,7,8,12,13,17,19-octa-alkyl- and 1,2,3,7,8,12,13,17,18,19-deca-alkyl-tetradehydrocorrin salts (I; $R^1 = H$, alkyl, $R^2 = R^3 = R^4 = \text{alkyl}$) at elevated temperature and pressure has been shown² to give the corresponding nickel AD-didehydrocorrin salts (IV). We have now examined the hydrogenation of nickel 1,7,8,12,13,19-hexamethyltetradehydrocorrin perchlorate (I; $R^1 = R^2 = H$, $R^3 = R^4 = \text{Me}$) in presence

² I. D. Dicker, R. Grigg, A. W. Johnson, H. Pinnock, and P. van den Broek, *J. Chem. Soc. (C)*, 1971, 536.

of Raney nickel at room temperature and 50 atmospheres of hydrogen, which gave the nickel β C-didehydrocorrin



SCHEME Reagents: i, H₂, R¹ = H, R² = H, Me, R³ = R⁴ = Me; ii, H₂, R¹ = H, R² = R³ = H, Me, R⁴ = H, Et; iii, H₂, R¹ = R² = R³ = Me, R⁴ = Et; iv, R = Me, Et; v, H₂; vi, NaOH-O₂, R¹ = H, R² = R³ = Me, R⁴ = Et; vii, NaOH-O₂, R¹ = R² = R³ = Me, R⁴ = Et

salt (V; R¹ = R² = H, R³ = R⁴ = Me). This compound was identified from its n.m.r. spectrum (see Experimental section for assignments) and by the

³ The term 'iso-corrinoid' has been used to describe the isomeric products formed from a variety of corrinoids by equilibration with strong acids (e.g. W. Friedrich and M. Moskophidis, *Z. Naturforsch.*, 1968, **23b**, 804; K. Bernhauer, H. Vogelmann, and F. Wagner, *Z. physiol. Chem.*, 1968, **349**, 1281), but the term was later replaced by 'neo-corrinoid.' It was originally thought that the isomerism might involve the 1-Me and the 19-H substituents, i.e. *cis* instead of the usual *trans* but it is now known to involve the configuration of the C-13 substituents [R. Bonnett, J. M. Godfrey, and V. B. Math, *J. Chem. Soc. (C)*, 1971, 3736].

similarity of its u.v. spectrum to those of the corresponding octa-alkyl derivatives.² It was identical with the compound obtained by base-catalysed dehydrogenation of nickel 1,7,8,12,13,19-hexamethylcorrin perchlorate² (II; R¹ = R² = H, R³ = R⁴ = Me). Further hydrogenation of the salt (V; R¹ = R² = H, R³ = R⁴ = Me) or longer hydrogenation of (I; R¹ = R² = H, R³ = R⁴ = Me) gave mixtures of the corresponding corrin and 4,5-dihydrocorrin isolated as amorphous salts, although on occasion each was obtained apparently uncontaminated with the other.

We have therefore re-examined the hydrogenation of nickel 1,3,7,8,12,13,17,19-octamethyltetrahydrocorrin perchlorate at room temperature and 50 atmospheres and have obtained the corresponding nickel β C-didehydrocorrin (V; R¹ = H, R² = R³ = R⁴ = Me) along with corresponding nickel corrin perchlorate.² As the latter compound yields nickel β C-didehydrocorrin perchlorate by alkaline dehydrogenation, an overall yield of ca. 65% of the didehydrocorrin salt was obtained. The hydrogenations of the nickel tetrahydrocorrin salts to either of the didehydrocorrins are probably the consequence of thermodynamic and kinetic control. A better yield (75%) of the nickel β C-didehydrocorrin perchlorate (V; R¹ = R² = R³ = R⁴ = Me) is obtained when 10% palladium-carbon in acetic acid is used as catalyst.

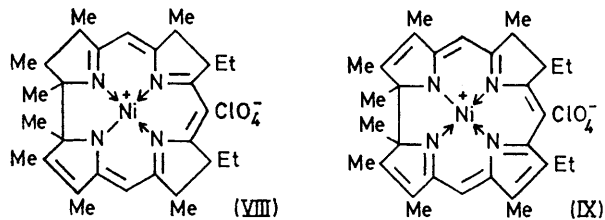
Corrins and Dihydrocorrins (Hexa- and Octa-alkyl Series).—More vigorous hydrogenations of the nickel 1,3,7,8,12,13,17,19-octa-alkyltetrahydrocorrin perchlorates have been shown to yield the corresponding nickel corrin perchlorates,² but we have now found that, as with nickel β -unsubstituted 1,19-dimethyltetrahydrocorrin perchlorate,¹ the hydrogenation product may be contaminated with the corresponding nickel 4,5-dihydrocorrin perchlorate (III; R¹ = H, R² = R³ = Me, R⁴ = Et). The products were separated by chromatography of the chlorides, the less polar compound being the amorphous corrin salt (II; R¹ = H, R² = R³ = Me, R⁴ = Et). The corresponding dihydrocorrin perchlorate was obtained as pale yellow crystals, the electronic spectrum of which was similar to that of the β -unsubstituted analogue.

Isocorrins³ and Dehydroisocorrins (Deca-alkyl Series).—Vigorous hydrogenation of nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyltetrahydrocorrin perchlorate or the corresponding α D-didehydrocorrin salt did not yield the nickel corrin salts but instead a crystalline perchlorate was obtained which was identical with a product obtained previously⁴ by hydrogenation of the nickel tetrahydrocorrin perchlorate and which had been formulated provisionally as the nickel monodehydrocorrin salt (VIII). The formation of this compound rather than the corrin salt was attributed to steric hindrance between the alkyl groups at C-1 and C-2, and between those at C-18 and C-19.

The results of a further study of the hydrogenation of

⁴ D. Dolphin, R. L. N. Harris, J. L. Huppertz, A. W. Johnson, and I. T. Kay, *J. Chem. Soc. (C)*, 1966, 30.

nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyltetrahydrocorrin perchlorate (I; $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$), have necessitated a modification of the structure (VIII), and they permit an overall picture of

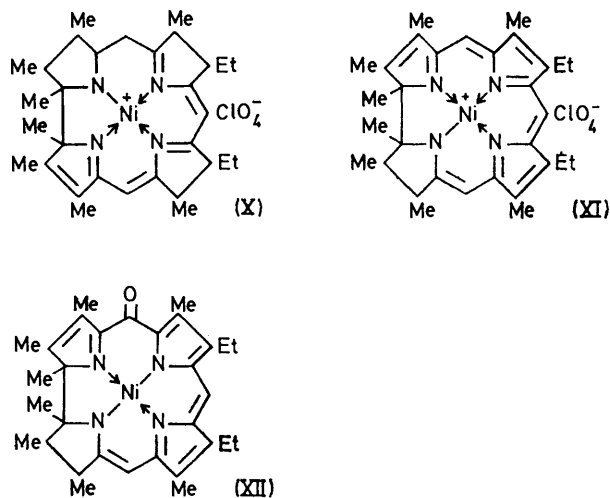


the course of the reaction after the AD-didehydrocorrin stage (IV; $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) to be given, and an assessment of the effect of the alkyl substituents to be made. Thus, hydrogenation of (I; $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) at 15–20° with 100 atmospheres of hydrogen in presence of 5% palladium-barium sulphate for 5 days gave a mixture of products partially separated by column chromatography. A red fraction contained, according to its n.m.r. spectrum, mainly the nickel ACD-tridehydrocorrin salt (IX)⁵ contaminated with the corresponding tetrahydrocorrin formed by aerial dehydrogenation. An orange fraction was purified by t.l.c. of its chloride salt, which gave a main product isolated as its crystalline perchlorate. The n.m.r. spectrum (see Experimental section for assignments) suggested that the tetrahydrocorrin has suffered hydrogenation in two rings and at one *meso*-position and thus structure (VI; $R = \text{Et}$), supported by elemental analysis, containing seven double bonds is suggested for the product. The break at C-5 in the chromophore resulted in a hypsochromic shift of 33 nm in the visible spectrum compared with that of the corresponding AD-didehydrocorrin perchlorate (IV; $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) which is similar to the difference (28 nm) in absorptions in the visible spectra of the nickel corrin perchlorate (II; $R^1 = \text{H}$, $R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) and the corresponding dihydrocorrin (III; $R^1 = \text{H}$, $R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$).¹ Amorphous preparations of (VI) had been obtained previously in our laboratory from a hydrogenation of the nickel tetrahydrocorrin perchlorate (I; $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) at room temperature with 100 atmospheres of hydrogen for 26 h in presence of a 10% palladium-carbon catalyst,⁵ and also by vigorous zinc-acetic acid reduction of the same salt or the corresponding nickel AD-didehydrocorrin perchlorate (IV; $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$).⁶ The analogous decamethyl derivative (VI; $R = \text{Me}$) was also prepared and purified as described above to yield orange prisms and again the observed spectra were in accord with the suggested structure. In contrast, in the absence of the C-2 and C-18 methyl groups, hydrogenation of the nickel tetrahydrocorrin salt (I; $R^1 = \text{H}$, $R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) at room temperature with 100 atmospheres of hydrogen in presence of 10% palladium-carbon catalyst, gave the corresponding nickel dihydrocorrin salt (III);

$R^1 = \text{H}$, $R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) as an amorphous solid, thus emphasising the profound effect of the C-2 and C-18 substituents on the course of the hydrogenation.

The crystalline product obtained from the hydrogenation of the nickel tetrahydrocorrin perchlorate (I; $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) under more vigorous conditions, *viz.* at 160° and 120 atmospheres of hydrogen in presence of W2 Raney nickel and believed to be a monodehydrocorrin nickel perchlorate (VIII) has been referred to above. This hydrogenation has been repeated and the product shown to be a mixture by chromatography of the chloride salt. The main product was isolated as a crystalline orange perchlorate, and the visible spectrum corresponded to that of the product reported earlier.⁴ The n.m.r. spectral evidence suggests that only one of the A and D rings has suffered hydrogenation and it therefore remains to make a choice between structures (VII) and (X), of which the former is preferred because of the sharp n.m.r. singlet at τ 7.97 for the two β -methyl substituents indicating that they are located in similar environments, *i.e.* on the isolated double bond of (VII). The structure (VII) for this compound had been considered earlier.⁶ Attempts to effect further hydrogenation of the macrocycle were unsuccessful. It is proposed to use the term isocorrin for the ring system of (VII) and thus the related ring system (VI) becomes a derivative of 17,18-dehydroisocorrin or D-mono-dehydroisocorrin.

When the nitrate of (I; $M = \text{Ni}$, $R^1 = R^2 = R^3 = \text{Me}$, $R^4 = \text{Et}$) was hydrogenated and the crude product subjected to the same work-up procedure, a small quantity of a red compound was obtained which, from its visible spectrum (bathochromic shift of *ca.* 9 nm from that of the nickel BC-didehydrocorrin salt²) is formulated as the nickel ABC-tridehydrocorrin perchlorate (XI).



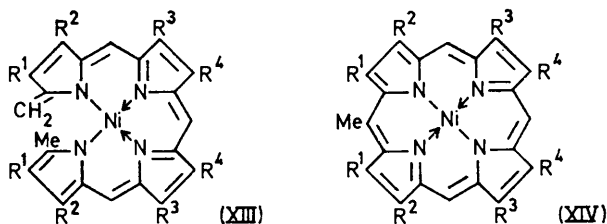
A small amount of a green neutral compound was isolated together with (XI), and although it was not crystallised, the visible spectrum was similar to that of

⁵ H. Pinnock, Ph.D. Thesis, University of Nottingham, 1969.

⁶ I. D. Dicker, Ph.D. Thesis, University of Nottingham, 1969.

the 5-oxo-derivative obtained² from the nickel β -didehydrocorrin perchlorate (V; $R^1 = H$, $R^2 = R^3 = Me$, $R^4 = Et$). The mass spectrum, however, suggested that the green by-product was (XII) derived by oxidation of (XI). Treatment of the macrocycle (XII) with acid gave a red-purple salt with the expected visible spectrum (*i.e.* for a 5-hydroxy-derivative) but attempts to isolate the salt merely caused reversion to the original 5-oxo-derivative as had been observed for related compounds.^{2,7}

Useful structural information has been obtained from mass spectroscopic studies of these macrocyclic compounds. As all the compounds are salts, they are relatively involatile and therefore require high temperatures to obtain a satisfactory ion flow rate. In the nickel tetrahydrocorrin nitrates (I; $X = NO_3$), the base peak occurred at ($M^+ - 1$) as a result of loss of HNO_3 , which is attributed to a fission of the macrocycle and formation of the neutral complex (XIII). However, the less volatile perchlorate (I; $X = ClO_4$) showed both ($M^+ - 1$) and ($M^+ - 3$) peaks, the latter being the stronger, and in the case of the very involatile β -unsubstituted nickel and cobalt 1,19-dimethyltetrahydrocorrin perchlorates, the base peak was at ($M^+ - 3$) and no ($M^+ - 1$) peak was observed at all. The ($M^+ - 3$) peak may be associated with rearrangement involving dehydrogenation to the corresponding nickel *meso*-methylporphyrin (XIV), a reaction of the perchlorates which is known to occur on thermolysis.⁸ This behaviour was apparently confined to the tetrahydrocorrin perchlorates and was not observed with the hydrogenated species.



It has been observed that the various salts resulting from hydrogenations of nickel tetrahydrocorrin salts fall into two distinct series with regard to the relation between base peak and the nature of the molecular cation. The first series is based on the nickel tetrahydrocorrin nitrates themselves (base peak $M^+ - 1$) and the other members result from the progressive hydrogenation of the 7,8- and 12,13- $\beta\beta$ -double bonds of rings B and C and finally the 4,5-*meso*-double bond. It is established that saturated bonds in these positions are readily dehydrogenated in the mass spectrometer and it will be recalled that base-catalysed dehydrogenation also occurs readily at the 7,8- and 12,13-positions.² The individual members of this series are shown in Table I.

The second series comprises the salts where hydrogenation has occurred in either or both of the A and D rings at the β -positions. The cations of the nickel ABC-

tridehydrocorrin (XI) and β -didehydrocorrin (V) were stable in the mass spectrometer and no dehydrogenation occurred in the A and D rings, so that in these cases the base peak corresponded to the molecular ion. Hydrogenation of the remaining three double bonds of nickel β -didehydrocorrin perchlorate (V), *i.e.* the 4,5-, 7,8-, and 12,13-positions, gives rise to saturated bonds which are known to suffer easy dehydrogenation during mass spectrometry, which agrees with the experimental findings (Table 2).

TABLE 1

Compound	Base peak	Position of dehydrogenation
Nickel tetrahydrocorrin nitrate (I; $X = NO_3$)	$M^+ - 1$	
Nickel β -didehydrocorrin perchlorate (IX) ⁵	$M^+ - 3$	7,8
Nickel β -didehydrocorrin perchlorate (IV) ²	$M^+ - 5$	7,8; 12,13
Nickel β -monodehydroisocorrin perchlorate (VIII)	$M^+ - 7$	7,8; 12,13; 4,5

TABLE 2

Compound	Base peak	Position of dehydrogenation
Nickel ABC-tridehydrocorrin perchlorate (XI)	M	
Nickel β -didehydrocorrin perchlorate (V)	M	
Nickel corrin perchlorate (II)	$M^+ - 4$	7,8; 12,13
Nickel isocorrin perchlorate (VII)	$M^+ - 6$	
Nickel 4,5-dihydrocorrin perchlorate (III)	$M^+ - 6$	7,8; 12,13; 4,5

Thus, additions to the β -double bonds of either or both of the A and D rings of the nickel tetrahydrocorrin salts causes a marked increase in stability of the macrocycle, an observation which could be of value in further synthetic applications of these compounds. Of the features in the mass spectra other than the base peaks, fragmentation ions due to loss of peripheral alkyl groups were observed as well as a number of $m/2e$ ions, as observed with alkylporphyrins.⁹ In addition, ions with mass in excess of that of the parent molecule were present (*ca.* 10% relative abundance) and resulted from thermally induced alkyl recombination.

EXPERIMENTAL

M.p.s were determined on a Kofler block and are uncorrected. Instruments used for spectroscopic determinations are the same as those detailed in an earlier paper.¹ Light petroleum refers to the fraction b.p. 60–80° and alumina for chromatography was Spence type H.

Nickel 8,12-Diethyl-1,2,3,7,13,17,18,19-octamethyl-17,18-dihydroisocorrin Perchlorate (VI; $R = Et$).—Nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyltetrahydrocorrin perchlorate³ (500 mg) in methanol (50 ml) was hydrogenated with 100 atmospheres of hydrogen at 15–20° for 120 h in the presence of 5% palladium-barium sulphate (1.0 g). The catalyst was removed by filtration and the solution was evaporated under reduced pressure. The residue was

⁸ R. Grigg, A. W. Johnson, K. Richardson, and K. W. Shelton, *J. Chem. Soc. (C)*, 1969, 655.

⁹ A. H. Jackson, G. W. Kenner, K. M. Smith, R. T. Aplin, H. Budzikiewicz, and C. Djerassi, *Tetrahedron*, 1965, **21**, 2913.

⁷ A. Hamilton and A. W. Johnson, *J. Chem. Soc. (C)*, 1971, 3879.

chromatographed slowly on a column (2.5 × 40 cm) of silica gel (60–120 mesh) with ethanol-free chloroform, the eluate being collected in 50 ml fractions. Elution was continued until the eluate was a weak purple colour. The eluate was collected in four fractions. (i) A small pink neutral fraction was obtained from the initial 6 × 50 ml fractions with λ_{\max} (very intense) 515 and 548 nm which suggested that the product was a nickel porphin, presumably nickel 8,12-diethyl-2,3,7,13,17,18-hexamethylporphin. (ii) Next orange-red fractions containing a component showing a strong band at 425 nm were obtained. These fractions were combined and concentrated under reduced pressure and the residue was dissolved in methanol (20 ml). Sodium hydroxide solution (2M; 10 ml) was added and the mixture was stirred at 20° for 30 min. The solution was neutralised with 2M-hydrochloric acid and further 2M hydrochloric acid (100 ml) then added. The orange-red oil which deposited was dissolved by the addition of methanol and the resulting solution saturated with sodium chloride. After stirring at room temperature for 3 days, water (500 ml) was added and the mixture was extracted with dichloromethane (4 × 100 ml). The extracts were dried (MgSO₄), concentrated to a small volume (ca. 10 ml), and the solution was applied to 12 silica gel t.l.c. plates (20 × 20 cm, 0.5 mm thickness). The plates were then eluted repetitively with chloroform for ca. 10 days and the main orange band was removed and extracted with methanol. Aqueous sodium perchlorate solution was added and the mixture was extracted with dichloromethane (4 × 50 ml). The extracts were dried (MgSO₄), evaporated to dryness, and the residue was crystallised twice from dichloromethane–light petroleum to give the product as lustrous, orange-brown needles (59 mg, 11.8%) of the *dehydroisocorrin perchlorate*, m.p. 255–257° (Found: C, 59.45; H, 6.8; N, 9.05. C₃₁H₄₃ClN₄NiO₄ requires C, 59.1; H, 6.85; N, 8.9%), λ_{\max} 261 (ε 24,900), 277 (22,230), 315 (10,680), and 425 (16,300) nm, λ_{inf} 358 (ε 8600) and 498 (2075) nm, τ 4.23, 4.30 (overlapping s, 10- and 15-H), 6.43–7.53br (m, 4-H, 5-H₂, and β-protons on the reduced rings), 7.80, 7.87, and 7.95 (overlapping s, 2-, 3-, 17-, and 18-Me), 8.25–9.07 (m, 19-Me and alkyl substituent protons of reduced rings), and 9.22 (1-Me), *m/e* 544, 542, 540, 538, 524, 522 (*M*⁺ – 7, 100%), 506 (70), 492, 478, 463, 272, 271, 270, 269, 262, 261, 253, 246, 239, and 231. (iii) Six fractions where the most intense band in the visible spectrum was at 340–343 nm were combined, concentrated under reduced pressure, and the residue was crystallised three times from dichloromethane–light petroleum at room temperature under nitrogen to give red needles (48 mg, 9.8%), of impure nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyl-*ACD*-tridehydrocorrin perchlorate (*cf.* ref. 4), m.p. >300°, λ_{\max} 273, 340, 460, and 525 nm, τ 2.87, 3.22, 3.50 (all s, 15-, 10-, and 5-H respectively), 6.90 (q, 12-H₂), 7.28–7.67 (overlapping s, Me of rings A, c, and D), 8.27–8.93 (m, alkyl groups of ring B), and 9.25 (2s, 1- and 19-Me), in addition signals at τ 2.33 and 2.43 (1:2) indicated the presence of ca. 20% of the parent tetradecahydrocorrin salt, *m/e* 540, 538, 524, 522 (*M*⁺ – 3, 100%), 506, 492, 478, 463, 261, 253, 246, 239, 231. (iv) The remaining red-purple fractions were combined, and shown to be unchanged nickel tetradecahydrocorrin perchlorate.

Nickel 1,2,3,7,8,12,13,17,18,19-*Decamethyl*-17,18-*dehydroisocorrin Perchlorate* (VI; R = Me).—1,2,3,7,8,12,13,17,18,19-*Decamethyltetradecahydrocorrin* nickel perchlorate (100 mg) in methanol (25 ml) was

hydrogenated with 100 atmospheres of hydrogen at 15–20° for 26 h in the presence of 10% palladium–carbon (100 mg) (*cf.* ref. 4). The catalyst was separated and 2M-hydrochloric acid (100 ml) was added. The orange oil which precipitated was redissolved by the addition of methanol and the resulting solution was saturated with sodium chloride. The mixture was then treated as described for the 8,12-diethyl analogue (above) to give the *product* as lustrous, orange-brown prisms from dichloromethane–ethyl acetate (29 mg, 28.7%), m.p. 174–176° (Found: C, 57.65; H, 6.7; N, 8.9. C₂₉H₃₉ClN₄NiO₄ requires C, 57.9; H, 6.5; N, 9.3%), λ_{\max} 262 (ε 13,970), 278 (12,770), 315 (6610), and 426 (10,420) nm, λ_{inf} 354 (ε 6460) and 498 (1430) nm, τ 4.20, 4.32 (both s, 10- and 15-H), 6.52–7.55 (m, 4-H, 5-H₂, and β-protons on the reduced rings), 7.82, 7.88, 7.95, and 7.98 (overlapping s, 2-, 3-, 17-, and 18-Me), 8.58–9.18 (m, protons of alkyl groups on reduced rings and 19-Me), and 9.23 (s, 1-Me), *m/e* 516, 514, 512, 510, 496, 494 (*M*⁺ – 7, 100%), 480, 474, 464 (76%), 451, 449, 258, 257, 256, 255, 248, 247, 240, 239, 232, and 230.

Nickel 8,12-*Diethyl*-1,2,3,7,13,17,18,19-*octamethylisocorrin Perchlorate* (VII).—8,12-*Diethyl*-1,2,3,7,13,17,18,19-*octamethyltetradecahydrocorrin* nickel perchlorate (I; M = Ni, R¹ = R² = R³ = Me, R⁴ = Et) (500 mg) in methanol (100 ml) was hydrogenated with 120 atmospheres of hydrogen at 160° for 2 h in the presence of W2 Raney nickel (2 ml). The hydrogenation product was filtered and 2M-hydrochloric acid (ca. 200 ml) was added immediately. Methanol was then added until complete solution was obtained followed by excess of sodium chloride, and the mixture was stirred for ca. 2 days during which time some darkening was observed. Water was added and the solution was extracted exhaustively with dichloromethane. The extracts were dried (MgSO₄), concentrated, and chromatographed repetitively on silica gel t.l.c. plates (0.5 mm thickness) with chloroform. After ca. 5 days a reasonable separation into three main bands was achieved. (i) A bright yellow band near the solvent front was extracted with methanol, sodium perchlorate was added, and the resulting solution was extracted with dichloromethane. The extracts were dried (MgSO₄), evaporated to dryness and the residue was treated with hydrochloric acid–sodium chloride and chromatographed as described above. The product (25 mg) was a mixture which from n.m.r. and mass spectra was shown to consist mainly of nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyl-*AD*-didehydrocorrin perchlorate² and the corresponding nickel 17,18-*dehydroisocorrin* perchlorate (above). (ii) The broad orange band in the centre of the plates was extracted with methanol and rechromatographed as described for band (i) when a further separation into a pale orange band and a red band was achieved. The former was extracted with methanol, sodium perchlorate was added, and the resulting solution was extracted with dichloromethane (4 × 50 ml). The extracts were dried (MgSO₄), evaporated, and the residue was crystallised twice from dichloromethane–light petroleum to give orange crystals (47 mg, 9.3%), m.p. >300° with previous darkening. This was identical with a product already described,³ and believed to be nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyldehydrocorrin perchlorate (Found: C, 59.1; H, 7.4; N, 8.95. Calc. for C₃₁H₄₅ClN₄NiO₄: C, 58.95; H, 7.15; N, 8.9%), λ_{\max} 251 (ε 17,410), 263 (15,540), 297 (12,780), 343 (7620), and 410 (20,940) nm, λ_{inf} 275 (ε 13,320), 286 (12,780), and 390 (13,190) nm, τ 4.35, 4.42 (both s, 10- and 15-H), 6.7–7.4

(m, 4-H, 5-H₂, and β-protons on the reduced rings), 7.93 (s, split into 2 : 1 singlets by addition of hexadeuterio-benzene, 2 × Me substituents on β-double bond), 8.6—9.1 (m, protons of β-alkyl substituents on reduced rings), and 9.22 (s, 1-Me) (*cf.* ref. 3), *m/e* 542, 540, 527 (80%), 525 (*M*⁺ - 6, 100%), 522, 506, 495, 478, 465, 463, 263.5, 262.5, 261, 255, 240, 238, and 231, identical with that of the product prepared previously.³ In the mass spectrum of the corresponding nitrate³ an additional ion at *m/e* 530 (50%) was observed.

The remaining bands of the chromatogram were extracted as described above but the products were amorphous solids which were not purified further. The bulk of the product (270 mg) consisted of overlapping bands which were mixtures of compounds. Further separation of this material was not attempted.

An attempted hydrogenation of nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethylisocorrin perchlorate in methanol at 170° with 125 atmospheres of hydrogen for 6 h in presence of W2 Raney nickel gave mainly unchanged starting material. Attempted dehydrogenations of the same material or of the corresponding 17,18-dehydro-derivative (see above) or of nickel 8,12-diethyl-1,3,7,13,17,19-hexamethyl-4,5-dihydrocorrin perchlorate (see below) by dissolving the sample (10 mg) in methanol (20 ml) containing sodium hydroxide (5 mg) and water (5 ml) were also negative. The mixture was heated under reflux for 2 h and then poured into water (100 ml) containing sodium perchlorate. The mixture was extracted with dichloromethane, dried (MgSO₄) and evaporated, and the visible spectrum of the residue was determined.

Hydrogenation of Nickel 8,12-Diethyl-1,2,3,7,13,17,18,19-octamethyltetrahydrocorrin Nitrate (I; R¹ = R² = R³ = Me, R⁴ = Et, X = NO₃).—The nitrate (100 mg) in methanol (30 ml) was hydrogenated with 120 atmospheres of hydrogen at 160° for 2 h in presence of W2 Raney nickel. During the filtration of the hydrogenation product and subsequent treatment with hydrochloric acid–sodium chloride, considerable darkening occurred giving a deep red solution. Chromatography was carried out as described in the previous experiment giving three main bands. (i) The neutral, dark green band which was obtained first was extracted with methanol, diluted with water, and then extracted with chloroform. The extracts were dried (MgSO₄) and concentrated to give a dark green oil which solidified to an amorphous solid (9 mg), *m.p.* >300°, which could not be crystallised, λ_{max.} (i) (CHCl₃) 419, 615, and 672 nm, (ii) (CHCl₃ + trace CF₃CO₂H) 342 and 560 nm, *m/e* 558, 556, 542, 540 (87.5%), 525, 503, 443, 429, 415, 369, 355, 341, 295, 281, 270, 221 (100%), and 207. These properties were consistent with the structure nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyl-5-oxo-ABC-tridehydrocorrin (XII). (ii) A polar orange band was extracted with methanol, sodium perchlorate was added, and the resulting solution was extracted with dichloromethane. The extracts were dried (MgSO₄) and evaporated and the residue was crystallised from dichloromethane–light petroleum to give orange crystals (10 mg, 9.9%), *m.p.* >300° with previous darkening. This product was shown by its visible and n.m.r. spectra to be nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethylisocorrin perchlorate (see above). (iii) A polar red band was extracted as for band (ii) but in this case the product could not be crystallised. It was dissolved in methanol (15 ml), sodium perchlorate was added, and the product (7 mg), *m.p.* >300°, was separated and dried over

P₂O₅ *in vacuo*, λ_{max.} 342, 408, and 560 nm, λ_{inf.} 388 and 534 nm, τ 3.10br (s, 5-, 10-, and 15-H), 6.5 (q, *J* 7 Hz, CH₂ of 8- and 12-Et), 7.83, 7.92 (s, Me on β-double bonds), and 8.5—9.17 (m), *m/e* 554, 540, 525 (*M*⁺, base peak), 506, 495, 280, 270, 269, 261.5 (*m/2e*), 257, 256, 255, and 254. These properties correspond with the structure nickel 8,12-diethyl-1,2,3,7,13,17,18,19-octamethyl-ABC-tridehydrocorrin perchlorate although the product was not completely purified.

Nickel 8,12-Diethyl-1,3,7,13,17,19-hexamethylcorrin Perchlorate (II; R¹ = H, R² = R³ = Me, R⁴ = Et) and *Nickel 8,12-Diethyl-1,3,7,13,17,19-hexamethyl-dihydrocorrin Perchlorate* (III; R¹ = H, R² = R³ = Me, R⁴ = Et).—Nickel 8,12-diethyl-1,3,7,13,17,19-hexamethyltetrahydrocorrin perchlorate (I; R¹ = H, R² = R³ = Me, R⁴ = Et) (103 mg) in methanol (25 ml) was hydrogenated with 100 atmospheres of hydrogen at 160° for 2 h in the presence of W2 Raney nickel (0.5 ml) (*cf.* ref. 2). The catalyst was separated and 2M-hydrochloric acid (100 ml) was added to the hydrogenation product. The orange oil which precipitated was redissolved by the addition of methanol and the solution was saturated with sodium chloride and stirred overnight. Water was then added, the mixture was extracted with dichloromethane (4 × 50 ml), and the extracts were dried (MgSO₄) and concentrated (to *ca.* 20 ml). The solution was chromatographed on silica gel t.l.c. plates (0.5 mm thickness) with chloroform saturated with sodium chloride repeatedly for several days until the two major yellow bands were completely separated. The less polar yellow band was extracted into methanol, sodium perchlorate was added followed by water, and the mixture was extracted well with dichloromethane. The extracts were dried (MgSO₄) and concentrated under reduced pressure but all attempts at crystallisation of the residue from a wide range of solvent systems failed. The residue was therefore dissolved in methanol (15 ml) and the perchlorate salt of the product was precipitated by the addition of aqueous sodium perchlorate solution. The amorphous product was separated and dried (9 mg, 8.6%) over P₂O₅ *in vacuo*. The product was shown by its electronic and n.m.r. spectra to be nickel 8,12-diethyl-1,3,7,13,17,19-hexamethylcorrin perchlorate (*cf.* ref. 2) (II; R¹ = H, R² = R³ = Me, R⁴ = Et), *m/e* 530, 518, 516, 514, 501, 499 (*M*⁺ - 4), 485, 483, 469, 454, 439, 425, 410, 258, 257, 250.5 (*m/2e*), 249.5 (*m/2e*), 242, 234.5 (*m/2e*), 227, and 219.

The more polar yellow band was extracted into methanol, sodium perchlorate was added followed by water, and the mixture was extracted with dichloromethane (4 × 50 ml). The extracts were dried (MgSO₄) and evaporated to dryness under reduced pressure. The residue was crystallised by the slow controlled evaporation of a solution in dichloromethane–light petroleum under a stream of nitrogen to give pale yellow clusters of needles of the *dihydrocorrin* (III; R¹ = H, R² = R³ = Me, R⁴ = Et) (12 mg, 11.5%) (Found: C, 56.95; H, 7.1; N, 8.75. C₂₅H₄₃ClN₄NiO₄ requires C, 57.25; H, 7.05; N, 9.2%), λ_{max.} 264 (ε 9540), 300 (12,060), 347 (4140), and 408 (15,130) nm, λ_{inf.} 278 (ε 8820) and 386 (9000) nm, τ 4.43, 4.58 (both s, 10- and 15-H), 8.43—9.18 (m, protons of β-methyl groups, 8- and 12-CH₂Me, and 1- and 19-Me), the remaining protons could not be assigned specifically but were present as a rather weak, broad multiplet at τ 6.0—8.4, no singlet was present at τ 7.8—8.0 indicating that all the β-double bonds had been reduced, *m/e* 516, 514, 501, 499 (*M*⁺ - 6, 100%), 484, 469, 454, 439, 425, 410, 258, 257, 249.5 (*m/2e*), 242, 234.5 (*m/2e*), 227, and 205.

Nickel 1,7,8,12,13,19-Hexamethyl-BC-didehydrocorrin Perchlorate (V; $R^1 = R^2 = H$, $R^3 = R^4 = Me$).—Nickel 1,7,8,12,13,19-hexamethyltetrahydrocorrin perchlorate (I; $R^1 = R^2 = H$, $R^3 = R^4 = Me$) (100 mg) in methanol (20 ml) was hydrogenated with 50 atmospheres of hydrogen at room temperature overnight in the presence of W2 Raney nickel (0.5 ml). The solution was filtered, water was added, and the product was extracted with dichloromethane. The extracts were dried ($MgSO_4$), concentrated, and chromatographed on silica gel (0.5 mm thickness) t.l.c. plates with chloroform–30% acetone. The main, bright red band was extracted with methanol, water was added, and the resulting solution was extracted exhaustively with dichloromethane. The extracts were dried ($MgSO_4$), evaporated to dryness, and the residue was crystallised from dichloromethane–light petroleum to give deep red needles (37 mg, 36.7%), m.p. $>300^\circ$, of *nickel 1,7,8,12,13,19-hexamethyl-BC-didehydrocorrin perchlorate* (Found: C, 55.35; H, 5.4; N, 10.4. $C_{25}H_{29}ClN_4NiO_4$ requires C, 55.2; H, 5.35; N, 10.3%), λ_{max} 230 (ϵ 27,710), 325 (33,680), 336 (36,670), and 549 (19,830) nm, λ_{inf} 247 (ϵ 23,360) and 386 (5700) nm, τ 2.7 (s, 10-H), 3.07 (s, 5- and 15-H), 6.05–6.43 (4H, m, 3- and 17-H₂), 7.43 (both s, each $2 \times \beta$ -Me), 7.67 (4H, m, 2- and 18-Hz, overlapping signal at τ 7.50), and 8.40 (s, 1- and 19-Me), m/e 458, 443 (M^+ , 100%), 425, 413 ($M^+ - 2Me$), 397, 221.5 ($m/2e$), 214, 206.5 ($m/2e$), and 199.

Nickel 1,3,7,8,12,13,17,19-Octamethyl-BC-didehydrocorrin Perchlorate (V; $R^1 = H$, $R^2 = R^3 = R^4 = Me$).—Nickel 1,3,7,8,12,13,17,19-octamethyltetrahydrocorrin perchlorate (I; $R^1 = H$, $R^2 = R^3 = R^4 = Me$) (200 mg) in methanol (90 ml) was hydrogenated with 30 atmospheres of hydrogen at room temperature overnight in presence of W2 Raney nickel (2 ml). The catalyst was removed, washed with dichloromethane, and the combined solutions were evaporated to dryness. The residue was dissolved in a small volume of dichloromethane and shaken with aqueous sodium perchlorate. The solvent was again removed and methanol (3 ml) was added to the residue. The solid product (84 mg) was the nickel BC-didehydrocorrin perchlorate and was identical with the sample prepared earlier.² The yellow filtrate was mainly the corresponding nickel corrin perchlorate (t.l.c.) which was dehydrogenated by adding 2N-sodium hydroxide with gentle shaking for 5 min. More of the nickel BC-didehydrocorrin (45 mg, total yield 129 mg, 64%) precipitated and was separated. The spectral properties agreed with those recorded earlier.²

Nickel 1,7,8,12,13,19-Hexamethylcorrin Perchlorate (II; $R^1 = R^2 = H$, $R^3 = R^4 = Me$) and *Nickel 1,7,8,12,13,19-Hexamethyl-4,5-dihydrocorrin Perchlorate* (III; $R^1 = R^2 = H$, $R^3 = R^4 = Me$).—(i) 1,7,8,12,13,19-Hexamethyltetrahydrocorrin nickel perchlorate (I; $R^1 = R^2 = H$, $R^3 = R^4 = Me$) (50 mg) in methanol (20 ml) was hydrogenated with 50 atmospheres of hydrogen at room temperature for 3 days in the presence of W2 Raney nickel (0.25 ml). The solution was filtered and 2M-hydrochloric acid (20 ml) was added followed by sufficient methanol to ensure complete solution. The mixture was saturated with sodium chloride

and stirred for 3 days. Water was then added and the solution was extracted exhaustively with dichloromethane. The extracts were dried ($MgSO_4$), concentrated, and chromatographed repeatedly on silica gel (0.5 mm thickness) t.l.c. plates in chloroform to give two main bands. The bright yellow band was extracted with methanol, sodium perchlorate was added, and the resulting solution was extracted with dichloromethane. The extracts were dried ($MgSO_4$) and evaporated to dryness. The residue could not be crystallised and it was therefore dissolved in methanol (10 ml) and sodium perchlorate solution was added. The amorphous product was separated and dried over phosphorus pentoxide *in vacuo* (7 mg, 11.8%), m.p. $>300^\circ$, and it was shown by comparison of its electronic, n.m.r., and mass spectra with those of an authentic specimen² to be nickel 1,7,8,12,13,19-hexamethylcorrin perchlorate.

The more polar orange band was extracted and isolated by a method similar to that used for the previous product to give amorphous orange perchlorate (24 mg), m.p. $>300^\circ$, which could not be crystallised, λ_{max} 345, 357, and 405 nm, λ_{inf} 384 nm, m/e 454, 443 ($M^+ - 6$), 413 ($M^+ - 6 - 2Me$; 45%), 397, 357, 221, and 206.5 ($m/2e$). This product is therefore formulated as *nickel 1,7,8,12,13,19-hexamethyl-4,5-dihydrocorrin perchlorate*.

(ii) 1,7,8,12,13,19-Hexamethyl-BC-didehydrocorrin nickel perchlorate (see above) (10 mg) in methanol (10 ml) was hydrogenated with 100 atmospheres of hydrogen at 170° for 2.5 in the presence of W2 Raney nickel (0.05 ml). The resulting solution was filtered, water was added, and the solution was extracted with dichloromethane. The extracts were dried ($MgSO_4$), concentrated, and chromatographed on a silica gel column with dichloromethane–30% acetone. The major orange fraction was collected and evaporated to dryness. The residue was dissolved in methanol (10 ml), sodium perchlorate solution was added and the amorphous orange product, which could not be crystallised, was separated and dried over P_2O_5 *in vacuo* (8 mg, 78.6%), m.p. $>300^\circ$. The product was shown by the identity of its electronic, n.m.r. and mass spectra to be nickel 1,7,8,12,13,19-hexamethylcorrin perchlorate.

(iii) 1,7,8,12,13,19-Hexamethyl-BC-didehydrocorrin nickel perchlorate (see above) (10 mg) in methanol (10 ml) was hydrogenated with 100 atmospheres of hydrogen at 160° for 2 h in the presence of W2 Raney nickel (0.05 ml). The hydrogenation product was chromatographed and isolated as described above (7 mg). All attempts at crystallisation of the product failed, but on the basis of its electronic and mass spectra it was the nickel dihydrocorrin perchlorate (III; $R^1 = R^2 = H$, $R^3 = R^4 = Me$).

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