and dried to afford 4.4 g., m.p. 205–215°. Recrystallization from benzene afforded 3.7 g., m.p. 222–224°. From the benzene solution an additional 0.4 g. was recovered.

Formation of α,β-Diphenylpropionic Acid in the Reduction of α-Phenyl-*p*-methoxycinnamonitrile.—A mixture of 11.8 g. of α-phenyl-*p*-methoxycinnamonitrile, 8.0 g. of potassium hydroxide and 200 ml. of benzyl alcohol was refluxed for 90 minutes. The reaction mixture was worked up as described in the general procedure. The residue left after the steam distillation was dissolved in 50 ml. of hot 50% alcohol, and the semi-solid deposited was filtered by suction after several days. It was fractionated to yield 4.0 g., b.p. 190–198° (0.8 mm.), which after several recrystallizations from 50% alcohol afforded 0.65 g. of α-phenyl-β-(*p*-methoxyphenyl)-propionic acid, m.p. and mixed m.p. 121–123.3°. The mother liquor from the filtration of the crude acid, which contained an oily portion, was evaporated and fractionated to yield 1.5 g., b.p. 170–180° (0.8 mm.), which after several recrystallizations from petroleum ether afforded 0.6 g. of α,β-diphenylpropionic acid, m.p. 92–95°, mixed m.p. 94–96°.

REHOVOTH, ISRAEL

COMMUNICATIONS TO THE EDITOR

MOLECULAR WEIGHTS FROM STUDIES OF SEDIMENTATION AND DIFFUSION IN THREE-COMPONENT SYSTEMS

Sir:

One of the chief methods used to find molecular weights of proteins is by combining the results of sedimentation and diffusion experiments performed with systems of at least three components (protein, salt, water). Yet the study of interacting flows in liquid diffusion[1–7] has shown that Svedberg's equation[8] is not applicable to finding the molecular weight of a solute in a three-component system. This may be seen readily from the fact that four diffusion coefficients are required to describe the flows of the two solutes in a three-component system. Moreover, recent studies by Dunlop[5,7] have shown that the cross-term diffusion coefficients D_{12} and D_{21} are not in general negligible in comparison with the main diffusion coefficients D_{11} and D_{22}. The purpose of this communication is to derive an equation analogous to Svedberg's equation for use with three-component, non-electrolyte systems.

As a starting point, equation 22 of Hooyman[9] will be used (with somewhat different notation) to describe the flow of a solute in a centrifugal field. This equation was derived[9] by the methods of thermodynamics of irreversible processes.[10,11]

$$J_i = \sum_{j=1}^{2} L_{ij}\left[\omega^2 r(1 - \bar{v}_j\rho) - \sum_{k=1}^{2}\left(\frac{\partial \mu_j}{\partial c_k}\right)_{\substack{T,P,c_m\\(m\neq 0)}}\left(\frac{\partial c_k}{\partial r}\right)_t\right] \qquad (i = 1,2) \quad (1)$$

J = flow relative to the cell, ω = angular velocity of the rotor, r = distance from the center of rotation, $\bar{v}$ = partial specific volume (assumed constant), ρ = density of solution, μ = chemical potential per gram, c = concentration in g./ml., T = absolute temperature, P = pressure, t = time; for brevity $(\partial\mu_j/\partial c_k)$ will be written μ_{jk}. The phenomenological coefficients L_{ij}, which enter into both the term for sedimentation and the terms for diffusion, relate the flow of solute i to the "forces" causing the flow. This is apparent when equation 1 is written in the more compact form

$$J_i = -\sum_{j=1}^{2} L_{ij}\left(\frac{\partial \bar{\mu}_j}{\partial r}\right)_t \qquad (i = 1,2) \quad (2)$$

where $\bar{\mu}_j$ is the total potential, per gram, of j. Comparison of (1) with the practical flow equation used to measure sedimentation and diffusion coefficients

$$J_i = c_i s_i \omega^2 r - \sum_{k=1}^{2} D_{ik}\left(\frac{\partial c_k}{\partial r}\right)_t \quad (i = 1,2) \quad (3)$$

shows that

$$s_1 = \frac{1}{c_1}\left[L_{11}(1 - \bar{v}_1\rho) + L_{12}(1 - \bar{v}_2\rho)\right] \qquad (4)$$

$$D_{11} = L_{11}\mu_{11} + L_{12}\mu_{21} \qquad (5a)$$

$$D_{12} = L_{11}\mu_{12} + L_{12}\mu_{22} \qquad (5b)$$

An expression for the molecular weight of solute 1 (M_1) is obtained by solving (5a) and (5b) for L_{11} and L_{12} and then by substituting the results into equation (4)

$$s_1 = \left\{\frac{(1 - \bar{v}_1\rho)}{(c_1\mu_{11})}\left[\frac{D_{11} - D_{12}\mu_{21}/\mu_{22}}{(1 - \gamma)}\right] + \frac{c_2(1 - \bar{v}_2\rho)}{(c_2\mu_{22})} \times \left[\frac{(D_{12}/c_1) - D_{11}\mu_{12}/(c_1\mu_{11})}{(1 - \gamma)}\right]\right\} \qquad (6)$$

$$\gamma = (\mu_{12}\mu_{21}/\mu_{11}\mu_{22}) \qquad (6a)$$

$$c_i\mu_{ii} = \frac{RT}{M_i}\left[1 + c_i\left(\frac{\partial \ln y_i}{\partial c_i}\right)_{\substack{T,P,c_j\\(j\neq 0)}}\right] \qquad (6b)$$

When c_2 is held fixed and the sedimentation and diffusion coefficients are extrapolated to zero c_1, this relation becomes (since[5,6] $D_{12} \rightarrow 0$ as $c_1 \rightarrow 0$ and, by L'Hopital's rule, $\lim\limits_{c_1\rightarrow 0} (D_{12}/c_1) = (\partial D_{12}/$

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∂c_1), evaluated at $c_1 = 0$)

$$\lim_{c_1 \longrightarrow 0} s_1 = \frac{M_1(1 - \bar{v}_1\rho)D_{11}}{RT} \left\{ 1 + c_2 \left[\frac{M_2(1 - \bar{v}_2\rho)}{M_1(1 - \bar{v}_1\rho)} \right] \times \left[\frac{\frac{1}{D_{11}} \left(\frac{\partial D_{12}}{\partial c_1} \right)_{c_2,T,P} - \left(\frac{\partial \ln y_1}{\partial c_2} \right)_{c_1,T,P}}{1 + c_2 \left(\frac{\partial \ln y_2}{\partial c_2} \right)_{c_1,T,P}} \right] \right\} \quad (7)$$

where y_1 is the activity coefficient of solute 1.

In this form, the result bears a striking resemblance to Svedberg's equation.[8] Measurement of the required quantities presents no unusual difficulty. Provided that $s_1 >> s_2$, the determination of s_1 is straightforward. The Gouy diffusiometer has been used to determine the four diffusion coefficients of several three-component systems.[2,5,6,7] Certain other methods for determining the molecular weight of a solute in a three-component system contain terms of the form $c_2(\partial \ln y_1/\partial c_2)$: for example, light-scattering[12] and sedimentation equilibrium.[13]

I am much indebted to Dr. L. J. Gosting for helpful suggestions and advice.

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THE STRUCTURAL RELATIONSHIP OF DELTALINE, DELPHELINE AND LYCOCTONINE[1]

Sir:

The alkaloid deltaline has been chemically transformed into delpheline and the latter into desoxylycoctonine, a known degradation product of lycoctonine. These interconversions prove that lycoctonine, delpheline, and deltaline possess the same skeleton structure, and establish the functional relationship of these three important *Delphinium* alkaloids, thus unifying much hitherto unrelated structural evidence. Moreover, we have found that all three alkaloids occur together in *Delphinium barbeyi* Huth, along with traces of several other closely related bases.

Deltaline was isolated as the major base of *D. barbeyi* and *D. occidentale*. It melts at 193.5–194° (evac. cap.; cor.), $[\alpha]^{33}D$ −28.5° (CH_3OH). *Anal.* Calcd. for $C_{27}H_{41}NO_8$: C, 63.88; H, 8.14; N, 2.76; O, 25.22; CH_3 on carbon (3) 8.86; active H (1), 0.20; CH_3O (3), 18.34. Found: C, 63.83; H, 8.21; N, 2.79; O (Unterzaucher), 25.32; CH_3 on carbon (Kuhn–Roth), 7.49; active H (Zerewitinoff), 0.20; CH_3O (Zeisel), 18.75, 18.13. Deltaline was first isolated from *D. occidentale* by Couch.[2] An examination of specimens of deltaline given to one of us (M. C.) by Couch revealed the invariable presence of another alkaloid, delphoccine, not previously reported and not readily separable from deltaline except by chromatography. The presence of delphoccine (whose properties we shall describe elsewhere) in Couch's material accounts for the fact that Couch's formula and constants differ from ours. The functionality of deltaline is $C_{17}H_{18}(\text{-OCOCH}_3)(\text{-OCH}_2\text{O-})(\text{-OCH}_3)_3(>NCH_2CH_3)(>C\text{-}CH_3)(OH)$.[3,4]

Replacement of the hydroxyl group of deltaline with hydrogen and conversion of the acetoxyl group to hydroxyl produces delpheline.[5,6] Treatment of deltaline with highly purified thionyl chloride at room temperature yielded *chloroacetyldelpheline*, m.p. 173.3–173.5° (evac. cap.; cor.), $[\alpha]^{26}D$ −40.7° ($CHCl_3$). *Anal.* Calcd. for $C_{27}H_{40}ClNO_7$: C, 61.64; H, 7.66; Cl, 6.74; N, 2.66; O, 21.29. Found: C, 61.54; H, 7.66; Cl, 6.69; N, 2.65; O (Unterzaucher), 21.09. The reaction of chloroacetyldelpheline with $LiAlH_4$ in refluxing ethyl ether gave an excellent yield of delpheline, identical in m.p., mixed m.p., infrared spectrum, R_f value, and optical rotation with specimens isolated by us from *D. occidentale* and *D. barbeyi* and with a specimen kindly supplied by Dr. R. C. Cookson.

The chromic acid oxidation[7] of lycoctonine $[(C_{17}H_{19}(\text{-OH HO-})(\text{-OCH}_3)_4(>NCH_2CH_3)(>CCH_2OH)]$ yields the aldehyde, lycoctonal,[7] reducible to the base, desoxylycoctonine, containing two C-methyl groups.

We have synthesized desoxylycoctonine from delpheline in two steps. The secondary hydroxyl group of delpheline, corresponding to the acetoxyl group in deltaline, was methylated by means of sodium hydride and methyl iodide. The resulting *O-methyldelpheline* melts at 102.5–103° (evac. cap.; cor.); $[\alpha]^{24}D$ −6.3° ($CHCl_3$). *Anal.* Calcd. for $C_{26}H_{41}NO_6$: C, 67.37; H, 8.92; N, 3.02; CH_3O (4), 26.78. Found: C, 67.44; H, 9.07; N, 3.19; CH_3O (Zeisel), 24.6. Hydrolysis of the acetal function of O-methyldelpheline with hot 10% sulfuric acid yielded desoxylycoctonine, identical in m.p., mixed m.p., infrared spectrum, and R_f value with the product prepared from lycoctonine by the procedure of Edwards and Marion.[7]

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COMPOSITION AND ENZYMATIC SYNTHESIS OF N-ACETYLNEURAMINIC ACID (SIALIC ACID)

Sir:

Previous reports[1,2,3] indicated N-acetylneuraminic acid (NANA) to be an 11 carbon keto acid.

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