Catalysis by Reversed Micelles in Non-polar Solvents : Mutarotation of 2,3,4,6-Tetramethyl-α-D-Glucose in Benzene

By E. J. FENDLER, J. H. FENDLER,* R. T. MEDARY, and V. A. WOODS
(*Department of Chemistry, Texas A & M University, College Station, Texas* 77843)

Summary Micellar dodecylammonium propionate and dodecylammonium benzoate enhance the rate of 2,3,4,6-tetramethyl-α-D-glucose mutarotation in benzene by factors of 390 and 457; this acceleration is considerably greater than that due to hydronium ions or water in aqueous solutions.

THE catalytic power of enzymes has been frequently described in terms of a concerted general acid or base catalysis at the active sites for the substrate.[1] Since the active sites of many enzymes are in a relatively hydrophobic environment, model studies in non-polar solvents,[2,3] at interfaces,[4] and in aqueous micellar systems[5] have provided a better understanding of the mechanisms involved. Phospholipids are known to form micelles not only in water but in benzene as well.[6] An alternative approach is, therefore, to investigate reactions in the polar environment of reversed micelles in apolar solvents. We report the first observation of a reaction catalysed markedly by reversed micelles—the mutarotation of 2,3,4,6-tetramethyl-α-D-glucose, (**1**), in benzene. The mutarotation of (**1**) in benzene in the presence of α-pyridone has provided a model for the simultaneous transfer of two protons, *i.e.* bifunctional catalysis; in 0·05M α-pyridone in benzene the mutarotation rate is 50 times greater than in the presence of equivalent concentrations of phenol and pyridine.[3]

Dodecylammonium propionate, (**2**),[7] dodecylammonium benzoate, (**3**),[8] and (**1**)[9] were prepared and purified by established procedures. Reagent grade benzene was dried and stored over Linde 4A molecular sieves. The critical micelle concentrations of (**2**) and (**3**) in benzene have been determined at 37° using ^{1}H n.m.r. spectroscopy, to be $2{\cdot}0 \times 10^{-3}$M and $4{\cdot}7 \times 10^{-3}$M, respectively. In the presence of (**1**), however, these values are 4-fold smaller. Pseudo-first order rate constants for the mutarotation, k_ψ($k_\psi = k_{\text{forward}} + k_{\text{reverse}}$), have been determined in 50 mm thermostatted cells using a Bendix automatic recording polarimeter. The data, obtained from good linear plots, are given in the Table. Rate constants for the mutarotation, as a function of the concentration of (**2**) increase markedly in the region of the critical micelle concentration and exhibit a sigmoidal dependence followed by a plateau. Analogous substrate saturation kinetics have been observed for numerous micellar catalysed reactions in aqueous solutions.[5] In the plateau region the rate constant for the mutarotation of (**1**) in the presence of (**2**) in benzene ($k_\psi = 532{\cdot}0 \times 10^{-5}$ s^{-1}) is 390 times greater than that in pure benzene and catalysis by (**3**) is even greater. It is equally significant that rate constants for the mutarotation of (**1**) in water at pH = 5·43 ($k_\psi = 34{\cdot}5 \times 10^{-5}$ s^{-1}) or at the same pH in the presence of $2{\cdot}0 \times 10^{-2}$M α-pyridone ($k_\psi = 40{\cdot}8 \times 10^{-5}$ s^{-1}) at 24·6° are 15—13 fold smaller than that in benzene catalysed by (**2**). Catalysis of the mutarotation of (**1**) in benzene by (**2**) or (**3**) at the beginning of the plateau [$1{\cdot}0 \times 10^{-3}$M (**2**)] is, in fact, three orders of magnitude greater than that by hydronium ions in water.[10] Although the present results do not allow us to ascertain the site of catalytic interaction, (**1**) is likely to be solubilized at the charged interior of the reversed micelles and consequently the catalysis arises from favourable initial and transition state orientation toward the ammonium and carboxyl groups which provide sites for proton transfer. Implications of the present results in these and other systems are being studied.

TABLE

Mutarotation of 2,3,4,6-*tetramethyl-*α-D-*glucose,* (**1**), *in benzene in the presence of dodecylammonium propionate,* (**2**), *at* 24·6°[a]

Concentration of (**2**) (10^4,M)	k_ψ(10^5, s^{-1})
0·00	1·40 (1·8)[b]
0·10	1·80
1·00	12·8
5·00	73·6
10·0	146·0
25·0	335·0
50·0	472·0
100·0	556·0
200·0	522·0
500·0	553·0
500·0[c]	640·0
1000·0	518·0
1000·0[c]	632·0

[a] Initial concentration of (**1**) = $1{\cdot}7 \times 10^{-2}$M; [b] In "wet" (water saturated) benzene; [c] Dodecylammonium benzoate.

This work was supported in part by the U.S. Atomic Energy Commission. E.J.F. is a Career Development Awardee of The National Institutes of Health, U.S. Public Health Service.

(*Received, October 4th,* 1971; *Com.* 1730.)

[1] W. P. Jencks, "Catalysis in Chemistry and Enzymology", McGraw Hill, New York, 1969.
[2] F. M. Menger, *J. Amer. Chem. Soc.*, 1966, **88**, 3081; R. L. Snell, W. Kwok, and Y. Kim, *ibid.*, 1967, **89**, 6728.
[3] C. G. Swain and J. F. Brown, jun., *J. Amer. Chem. Soc.*, 1952, **74**, 2538; P. R. Rony, *ibid.*, 1968, 2824; P. R. Rony, *ibid.*, 1969, **91**, 4244, 6090.
[4] F. M. Menger, *J. Amer. Chem. Soc.*, 1970, **92**, 5965.
[5] E. H. Cordes and R. B. Dunlap, *Accounts Chem. Res.*, 1969, **2**, 329; E. J. Fendler and J. H. Fendler, *Adv. Phys. Org. Chem.*, 1970, **8**, 271.
[6] P. H. Elworthy, A. T. Florence, and C. B. Macfarlane, "Solubilization by Surface Active Agents", Chapman & Hall Ltd., London, 1968.
[7] A. Kitahara, *Bull. Chem. Soc. Japan*, 1956, **29**, 15.
[8] A. Kitahara, *Bull. Chem. Soc. Japan*, 1957, **30**, 586.
[9] E. S. West and R. F. Holden, *Org. Synth.*, 1940, **20**, 97.
[10] H. H. Huang, R. R. Robinson, and F. A. Long, *J. Amer. Chem. Soc.*, 1966, **88**, 1866; and references cited therein.