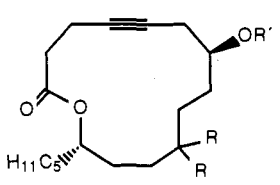
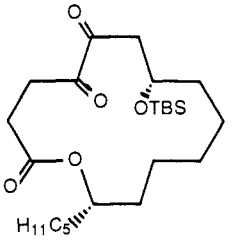
crodiolide from intermolecular esterification of the C(7)-hydroxyl group was observed.

Given that conventional methods for reductive removal of the dithiane (cf. Raney nickel) would also hydrogenate a triple bond and reduce a 1,2-diketone and, conversely, that oxidation of the acetylene could alter the dithiane (sulfoxide or sulfone formation), we chose the following two-step procedure for removal of the dithiane unit. Hydrolysis[20] of the dithiane of **6** (20 equiv of MeI, aqueous acetone, 60 °C, 4 h) provided ketone **7** which was con-





10

6 R,R = -S(CH$_2$)$_3$S- ; R′ = H
7 R,R = O ; R′ = H
8 R,R = H,H ; R′ = H
9 R,R = H,H ; R′ = TBS

verted to the tosylhydrazone [1.1 equiv of *p*-CH$_3$C$_6$H$_4$SO$_2$NHNH$_2$, *p*-TsOH, sulfolane/DMF (1:1), 100 °C, 15 min] and reduced (in one pot) with sodium cyanoborohydride[21] (4 equiv, 3 h, 100 °C, 35% of **8** from **6**). It was necessary to protect the C(7) hydroxyl [2 equiv of TBSCl, 2 equiv Et$_3$N, 4-PP (catalyst), DMF, 12 h, 88% of **9**][22] in order to oxidize the acetylene without competing ketone formation. Oxidation was then achieved without event by using sodium periodate (4.1 equiv) and catalytic ruthenium dioxide[13] [CH$_3$CN/CCl$_4$/H$_2$O (2:2:3)] to give the brightly yellow dicarbonyl compound **10** (74%). Deprotection of the C(7)-hydroxyl [pyridine·(HF)$_x$, THF][23] caused slow disappearance of the yellow color with the expected formation of synthetic gloeosporone (80%), identical with the natural product (500 MHz ^{1}H NMR, 75 MHz ^{13}C NMR, IR, MS, TLC (several solvent systems)).

The optical rotation $[\alpha]_D$ of synthetic gloeosporone was +52° (*c* = 0.71, CHCl$_3$)[24] with mp 117-118 °C, whereas $[\alpha]_D$ = -14° (*c* = 0.28 CHCl$_3$) and mp 108-110 °C were reported for the natural material.[25] With the absolute configuration derived from (*S*)-(+)-4-bromo-1,2-epoxybutane, the synthetic compound can be specified as 4*R*,7*S*,13*S* as shown in **A**.[25]

In conclusion, the first total synthesis of (+)-gloeosporone has been achieved in eleven steps from readily available starting materials and in 4.2% overall yield.[26]

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(24) The optical rotation in acid free CHCl$_3$ was found to be +58° (*c* 0.48) and in benzene, $[\alpha]_D$ = +79° (*c* 0.40).
(25) Upon purification of a very small sample of natural gloeosporone, the optical rotation increased to -30° (*c* 0.08, CHCl$_3$). Given the low concentration, we can only use this value as an indication that natural gloeosporone is levorotatory (we thank W. L. Meyer, University of Arkansas, for a sample of natural gloeosporone). Thus, the synthetic sample described here should be the enantiomer of the natural product. Since the submission of this communication, we have also prepared (-)-gloeosporone from (*R*)-malic acid. The optical rotation was found to be -61° (*c* 0.34, acid free CHCl$_3$) and $[\alpha]_D$ = -72° (*c* 0.34, benzene). Activity studies of both enantiomers are underway and will be reported in due course.
(26) All new compounds were characterized by 300 MHz ^{1}H NMR, IR, MS and, when stability allowed, elemental analysis to ±0.3%.

Phototropic Molecules. 1. Phase Transfer As a Method for Detecting Transient Species

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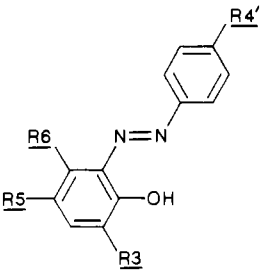
A light-induced large temporary change in the pK_a of an acid would have many practical uses. These include light-switched acid catalysis, light-powdered proton transport through a membrane, etc. The most obvious way of accomplishing this is to make use of the discovery[1] that the p*K*'s of the photoexcited states of compounds such as phenols or anilines differ enormously from the p*K*'s of these molecules in the ground states. Unfortunately, attempts to utilize these light-induced changes in acidity for chemical purposes[2] are likely to fail because the lifetimes of these photoexcited states are too short to effect an appreciable change in the pH of the solution.[3] What is needed is a reversible change in the pK_a of a species which is longer lived than an electronic excited state but sufficiently short lived to enable one to have many on/off cycles in a reasonably short time period.

While there are sophisticated methods for measuring the p*K*'s of excited states and the lifetimes of excited states, it would be useful to have a simple method for measuring temporary light-induced changes in p*K*'s, whilst simultaneously making certain that these temporary species are sufficiently long lived to pass through membranes or to engage in other chemical work. This paper describes such a procedure and applies it to the measurement of the pK_a's of three azophenols.



	R3	R5	R6	R4'
1 2-hydroxy-5-methylazobenzene	H	CH$_3$	H	H
2 2-hydroxy-3,5,6-trichloro-4'-methylazobenzene	Cl	Cl	Cl	CH$_3$
3 2-hydroxy-5,4'-dinitroazobenzene	H	NO$_2$	H	NO$_2$

trans-2-Hydroxyazobenzenes are known to have a diminished acidity which is due to the hydrogen bond between the phenolic hydroxyl and an azo nitrogen.[4] In the cis configuration the hydrogen bond is lost, and the acidity of the phenol is consequently enhanced. The thermal cis → trans reversion of *o*- and *p*-hydroxyazobenzenes and aminoazobenzenes is very fast.[5] Is the lifetime of the more acidic *cis*-azophenol long enough to effect useful chemical work, and is this enhanced acidity detectable by conventional chemical techniques?

A 50-mL solution of azophenol **1**, 4.56 × 10^{-5} M in toluene was stirred with 50 mL of 1.0 N aqueous NaOH in a 200-mL,

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Table I. Reversible Migration of 2-Hydroxy-4-methylazobenzene (1) from Toluene to 1.0 N Aqueous NaOH

condition[a]	[azophenol 1] in toluene (M)	[azophenoxide 1] in aq phase (M)
after stirring in the dark, 3 min	4.45×10^{-5}	0.110×10^{-5}
after 3 min irradiation and stirring	3.23×10^{-5}	1.51×10^{-5}
after 3 min further stirring in the dark	4.21×10^{-5}	0.143×10^{-5}
after 3 min further irradiation and stirring	3.17×10^{-5}	1.43×10^{-5}

[a] Aqueous and organic phases, 50 mL each, in a 200-mL thermostated, round-bottomed flask at 25.0 °C, inside a Rayonet reactor equipped with 350-nm lamps.

Table II. Acidity Constant Values, K_a, Obtained with Use of Eq 3 for Azophenols 1, 2 and 3

compd	K_A(dark)	K_A(light)
1[a]	2.92×10^{-11}	5.47×10^{-10}
2[b]	1.54×10^{-10}	9.38×10^{-8}
3[c]	7.63×10^{-7}	5.70×10^{-7}

[a] The aqueous phase in the phase-transfer experiment was 1.0 M NaOH. [b] The aqueous phase in the phase-transfer experiment was 0.10 M NaOH. [c] The aqueous phase in the phase-transfer experiment was pH 9.0 borax buffer.

thermostated, round-bottomed flask inside a Rayonet reactor equipped with 350-nm lamps. When the stirring was stopped and the light was turned off, the yellow azophenol color in the toluene phase was found to be somewhat bleached, and the azophenoxide color in the alkaline aqueous phase was found to be considerably enhanced. Stirring for a few minutes in the dark restored the original situation, returning the bulk of the azophenol to the toluene phase. This migration was reversible and could be repeated any number of times. (It should be emphasized that the color observed in the aqueous phase is always that of the *trans*-azophenoxide. After the light is turned off the color persists, because, in the absence of stirring, migration across the water/toluene phase boundary is imperceptibly slow.) Using the absorbance maxima of *trans*-azophenol **1** and *trans*-azophenoxide **1**, at 400 and 475 nm, respectively, yielded the extent of the migration from one phase to the other which is reported in Table I.

The transfer of the azophenol from the organic phase to the aqueous alkaline phase is governed by two equilibria. The first equilibrium, (1), is the partition coefficient of the azophenol

$$(\text{Ar-OH})_{\text{tol}} \overset{K_{PT}}{\rightleftharpoons} (\text{Ar-OH})_{\text{aq}} \quad (1)$$

$$(\text{Ar-OH})_{\text{aq}} + (\text{OH}^-)_{\text{aq}} \overset{K_a/10^{-14}}{\rightleftharpoons} (\text{ArO}^-)_{\text{aq}} + \text{H}_2\text{O} \quad (2)$$

$$K_a = \frac{(\text{Ar-O}^-)_{\text{aq}} 10^{-14}}{(\text{Ar-OH})_{\text{tol}} (\text{OH}^-)_{\text{aq}} K_{PT}} \quad (3)$$

between toluene and water, K_{PT}. Equilibrium (2), or $K_a/10^{-14}$, is the reaction of the aqueous azophenol with NaOH to form the aqueous azophenoxide. Combination of eq 1 and 2 yields eq 3, the expression for the aqueous acidity constant of the azophenol, K_a. To evaluate K_a an additional experiment is required, namely the independent measurement of K_{PT}. This was done for azophenols **1**, **2**, and **3**, both in the dark and under irradiation, and the results are shown in Table II. It can be seen that the ratio of K_a (light)/K_a(dark) for compounds **1** and **2** is quite substantial, or 18.7 and 609, respectively. The ratio for compound **3** is near unity, evidently, because the acid-strengthening effect due to the loss of the intramolecular hydrogen bond is here counteracted by the acid-weakening effect due to the loss of conjugation to the 4′-NO_2 in the nonplanar cis isomer.

The K_a(light) value measured by this procedure is the *effective acidity* of the azophenol under the phase-transfer conditions described in this experiment. It may be smaller than the acidity constant of the transient *cis*-azophenol, K_a(cis), due to incomplete conversion to the *cis*-azophenol at the photostationary state. It is however the K_a value of interest when endeavoring to design an experiment utilizing this light-enhanced acidity phenomenon for the purposes of light-powdered membrane transport or any other purpose involving chemical work.

Registry No. 1, 109997-28-6; **2**, 109976-80-9; **3**, 109997-29-7.

Phototropic Molecules. 2. A Light-Powered Hydrogen-Ion Pump

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The photolysis of water using solar radiation has received much attention in recent years.[1-3] While the photoproduction of H_2 and O_2 by the splitting of water is an obviously desirable form of photochemical solar energy conversion, there is another possible way of "splitting" water, namely the hydrolysis reaction, $H_2O \rightarrow H^+ + OH^-$. The present communication reports the first example of a light-powered liquid membrane[4] which accomplishes the hydrolysis of water.

Figure 1 shows a schematic representation of the requirements for light-powered proton transport across a liquid membrane. What is required is a lipophilic, weak acid (*trans*-AH) which is converted by light into a stronger acid (*cis*-AH) but reverts rapidly to the weak acid in the dark. In the liquid membrane, one side of which is illuminated and the other side dark, the stronger acid on formation donates a proton to the illuminated aqueous compartment. The conjugate base of the stronger acid (*cis*-A^-) ultimately finds itself in the dark portion of the organic phase where it reverts to *trans*-A^-. *trans*-A^- is the conjugate base of a weak acid and hence a strong base, capable of abstracting a proton from the dark aqueous compartment. This reforms *trans*-AH which is now ready for the next cycle. Each cycle forms one H^+ in the illuminated aqueous compartment and one OH^- in the dark aqueous compartment. For simplicity of presentation the comigration of a counterion (to maintain electrical neutrality in the two aqueous compartments) has been ommited from this scheme.

In the previous communication[5] it has been shown that 2-hydroxyazobenzenes are good candidates for the kind of phototropic proton carrier envisioned above. The lifetime of the cis isomer is long enough to enable it to pass through a phase boundary[5] yet short enough to permit many proton transport cycles per second.[6] The compound found to be most suitable was 2-hydroxy-3,5,6-trichloro-4′-methylazobenzene. Tetrabutylammonium picrate (Bu_4NPic) was used to provide a lipophilic counterion for the conjugate base (the Bu_4N^+ ion) as well as a mobile anion to maintain electrical neutrality in the aqueous compartments (the Pic^- ion). In view of the pK_a values of the phototropic acid[5] an initial pH of 12 was used in the two aqueous compartments. In order to obtain suitable partition of all the migrating species between the two phases it was also found necessary to add a considerable amount of salt (1.5 M Na_2SO_4)

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