

***p*-Toluenesulfonic Acid Adsorbed on Silica Gel: An Efficient Dehydrating Agent of Alcohols**

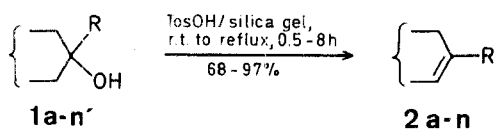
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Secondary and tertiary alcohols are efficiently dehydrated by reaction with *p*-toluenesulfonic acid supported on silica gel. In particular, the procedure allows the direct conversion of 3-hydroxy-steroids into Δ^2 -olefins or $\Delta^{3,5}$ -dienes, without passing through the mesylate or tosylate esters.

Several methods are available for the conversion of alcohols to olefins. Among them the direct dehydration of the alcohols with suitable reagents¹, and the elimination of their ester derivatives², are widely propagated. Many steroid secondary alcohols, which are resistant to acid-catalysed dehydration, can be efficiently converted into olefins only by elimination of their tosylate or mesylate esters in basic media³.

We now report a general method for the *direct* dehydration of secondary 3-hydroxy-steroids to Δ^2 -olefins or $\Delta^{3,5}$ -dienes, that avoids the above two-step sequence, by using *p*-toluenesulfonic acid adsorbed on silica gel as catalyst (Table). This reagent can be easily prepared by mixing chromatographic grade silica gel with 3% of its weight of hydrated *p*-toluenesulfonic acid dissolved in acetone. The removal of the solvent affords a white powder that can be stored in a desiccator for long periods of times without any appreciable loss of activity.



R = H, alkyl, phenyl

The procedure involves the adsorption of the alcohols, dissolved in dry benzene, on the reagent. After the completion of the reaction, the olefins, isolated from silica gel by elution with organic solvents, are obtained uncontaminated with by-products, other than small amounts of the starting materials.

Furthermore, while primary alcohols, e.g. dodecan-1-ol, submitted to the same treatment, are recovered unchanged, tertiary alcohols are dehydrated in a very rapid and efficient manner (Table). The resulting order of reactivity (benzylic > tertiary > homoallylic > secondary) suggests that the key-step of the process involves the formation of a carbenium ion; this assumption is supported by the observed regioselectivity (substrates **1l**, **1l'**, Saytzeff orientation favoured) and by the conversion of epimeric alcohols into the same olefin (substrates **1l**–**1n'**). Furthermore, a very fast process of epimerisation, clearly detectable by T.L.C. is found to precede the dehydration of both 1-phenyl-*cis*- and 1-phenyl-*trans*-4-*t*-butylcyclohexan-1-ol. An excellent regioselectivity (substrates **1j** and **1k**) has been noted in the formation of isomeric *endo*- and *exo*-olefins in the ratio of ~ 10/1.

In summary, *p*-toluenesulfonic acid adsorbed on silica gel represents a simple and efficient alternative to other dehydrating agents.

Table. Dehydration of Alcohols with *p*-Toluenesulfonic Acid Adsorbed on Silica Gel

Substrate	Product	Reaction Conditions		Yield ^a [%]	m.p. [°C] or b.p. [°C]/torr	
		Time [h]	Temperature [°C]		found	reported
		8	reflux	97	68–70°	69–70° ⁴
		8	reflux	90	108–110°	108–109° ⁵
		2	reflux	75	79–80°	80–81° ⁶
		2	reflux	69	83–85°	80–82° ⁷
		2	reflux	68	138–140°	139–142° ⁷
		2	reflux	73	109–112°	111–112° ⁸

Table. (Continued)

Substrate	Product	Reaction Conditions		Yield ^a [%]	m. p. [°C] or b. p. [°C]/torr	
		Time [h]/Temperature [°C]			found	reported
		2/reflux		69	148–150°	149–150° ⁷
		1/rt		91	112–114°/10	102–103°/5 ⁹
		1/rt		94	112–113°/8	113–115°/8 ¹⁰
		1/45°		98	—	—
		1/45°		92	—	—
		1/45°		87	80–81°	82–83° ¹¹
		1/45°		81		
		0.5/r. t.		90	125–126°	126–127° ¹²
		0.5/r. t.		85	124–126°	
		0.5/r. t.		95	108–110°/5	106–107°/4 ⁹
		0.5/r. t.		93	108–109°/5	

^a All the yields refer to isolated, chromatographically pure, compounds with the exception of products **2g** and **2k** where the final products are contaminated with small amounts of *exo*-isomers. The ratio of the isomeric olefins, determined by ¹H-N. M. R. spectroscopy, is respectively 92/8 (**2j**) and 91/9 (**2k**).

All the secondary steroid alcohols (Table) were purchased from Aldrich or Fluka and used as received. The other known carbinols were prepared by treatment of the corresponding ketones with a 20% excess of an appropriate Grignard reagent and their structures were confirmed by analytical and spectroscopic data. Hydrated *p*-toluenesulfonic acid (RP grade) was purchased from Carlo Erba.

Adsorption of *p*-Toluenesulfonic Acid on Silica Gel:

A solution of *p*-toluenesulfonic acid (3 g) in acetone (20 ml) is rapidly added to chromatographic grade silica gel (100 g; Merck Kiesel gel 60, particle size 0.063–0.200 mm, 70–230 mesh) under vigorous stirring. After 1 h, the solvent is removed under reduced pressure (2 torr) at 45–50°C for 6 h.

Dehydration of Alcohols to Alkenes (Table); General Procedure:

The alcohol (2.5 mmol) dissolved in dry benzene (170 ml) is rapidly added to the reagent (12 g) prepared as above and the mixture is stirred under the conditions given in the Table. Then, light petroleum

30–50°C, 70 ml) is added and the mixture is poured into a chromatographic column. The dehydration products are completely removed from silica gel by further elution with benzene/light petroleum (1/1, 250 ml) (products **2a**, **c**, **f**, **h–n'**) or light petroleum/ether (9/1, 300 ml) (products **2b**, **d**, **e**, **g**).

The structures of all the dehydration products have been confirmed by spectroscopic (I. R. and ¹H-N.M.R.) and analytical data.

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